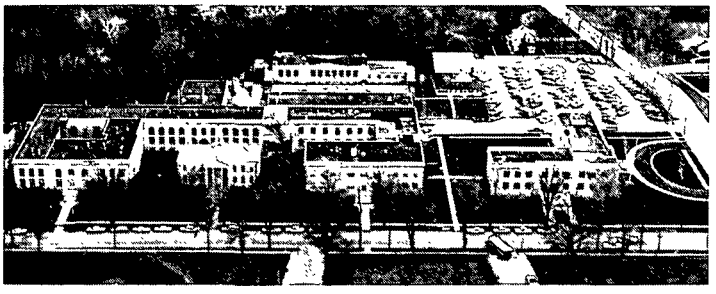


THE INSTITUTE OF PAPER CHEMISTRY, APPLETON, WISCONSIN

STATUS REPORTS

To The

Engineering Project Advisory Committee

March 26-27, 1987
The Institute of Paper Chemistry
Continuing Education Center
Appleton, Wisconsin

NOTICE & DISCLAIMER

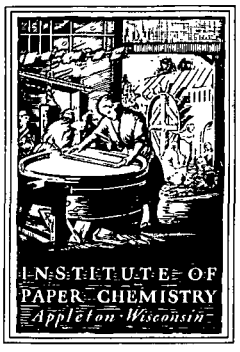
The Institute of Paper Chemistry (IPC) has provided a high standard of professional service and has exerted its best efforts within the time and funds available for this project. The information and conclusions are advisory and are intended only for the internal use by any company who may receive this report. Each company must decide for itself the best approach to solving any problems it may have and how, or whether, this reported information should be considered in its approach.

IPC does not recommend particular products, procedures, materials, or services. These are included only in the interest of completeness within a laboratory context and budgetary constraint. Actual products, procedures, materials, and services used may differ and are peculiar to the operations of each company.

In no event shall IPC or its employees and agents have any obligation or liability for damages, including, but not limited to, consequential damages, arising out of or in connection with any company's use of, or inability to use, the reported information. IPC provides no warranty or guaranty of results.

This information represents a review of on-going research for use by the Project Advisory Committees. The information is not intended to be a definitive progress report on any of the projects and should not be cited or referenced in any paper or correspondence external to your company.

Your advice and suggestions on any of the projects will be most welcome.



THE INSTITUTE OF PAPER CHEMISTRY
Post Office Box 1039
Appleton, Wisconsin 54912
Phone: 414/734-9251
Telex: 469289

February 23, 1987

TO: Members of the Engineering Project Advisory Committee

Enclosed is advance reading material for the March 26-27 meeting of the Engineering Project Advisory Committee. Included are status reports for active projects, an agenda, and a current committee membership list.

Rooms have been reserved in the Continuing Education Center, and meals will be provided as stated on the agenda. If you haven't already indicated your attendance, please do so at your earliest convenience by returning your registration form or calling Barbara Bisby at 414/738-3328.

For all Project Advisory Committee meetings, the Institute invites its member companies to send one or more representatives to attend the review sessions (first day) of any or all of the meetings. These invitations were mailed in January. PAC members from member companies are also welcome to attend the other meetings, and may stay in the CEC and attend meetings and meals of their choice, at no cost. If you wish to attend any of the other meetings, but haven't registered, please call Barbara Bisby to do so. A meeting schedule is enclosed for your information..

We look forward to meeting with you on March 26-27.

Sincerely,

Clyde

Clyde H. Sprague, Director
Engineering Division

CHS/el
Enclosures

THE INSTITUTE OF PAPER CHEMISTRY

Project Advisory Committee Fall Meetings
Member Dues - Funded Research Reviews

March 24, 25, 26, 30 and 31

1987

Continuing Education Center
Appleton, Wisconsin
(414) 734-9251

Committee	Review Schedule	Research Area*
Pulping Processes	Tuesday, March 24 8:30 AM - evening	Chemical Recovery: Recovery Furnace Processes Bleached Chemical Pulp: Pulping Oxygen Bleaching High Lignin Pulps: Brightness Stability Strength Development Microstructure of Wood Fibers Analytical Techniques
Paper Properties	Wednesday, March 25 8:30 AM - evening	Strength Improvement and Failure Mechanisms Board Properties and Performance Student Research Process, Properties, Product Relationships Internal Strength Enhancement On-line Measurement of Paper Mechanical Properties Tour of Paper Materials Division Labs
Engineering	Thursday, March 26 10:00 AM - evening	Corrosion: Kraft Liquor Corrosivity Corrosion Control in Paper Mills Corrosion in High Yield Pulping Corrosion-resistant Coatings Papermaking: Mechanics of Refining Higher Consistency Processing Wet Pressing Impulse Drying

*NOT IN ORDER OF AGENDA

Committee	Review Schedule	Research Area*
Forest Genetics	Monday, March 30 1:00 PM - evening	Somatic Embryogenesis Refined Protocols for Induction Norway and White Spruce White Pine Target Species Somatic Embryo Development/ Maturation Norway Spruce White Pine Plantlet Recovery Norway Spruce Exploratory Research Chloroplast Development Protoplast Culture Gene Transfer
Systems Analysis	Tuesday, March 31 1:00 PM - evening	MAPPS Simulator Development Continuing Module Development Performance Attribute Modeling Optimization with MAPPS MAPPS Applications and Field Experience

*NOT IN ORDER OF AGENDA

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* * * TENTATIVE AGENDA * * *

ENGINEERING
PROJECT ADVISORY COMMITTEE

March 26-27, 1987

Continuing Education Center (CEC)
The Institute of Paper Chemistry
Appleton, Wisconsin

Thursday, March 26, 1987

PROJECT REVIEWS

10:00am --	INTRODUCTION	Sprague/Rugowski
10:15am --	CORROSION AND MATERIALS ENGINEERING SECTION	
	- Fundamentals of Corrosion Control in Paper Mills	Yeske
	- Fundamentals of Kraft Liquor Corrosivity	Crowe
12:00pm --	LUNCH	
1:00pm	- Evaluation of Structural Coatings for Pulp and Paper Mills Service	Crowe
	- Corrosion in High Yield Pulping Processes	Crowe
1:30pm --	PAPERMAKING PROCESSES GROUP	
	- Fundamentals of Drying	Lavery
2:45pm --	BREAK	
3:00pm	- Demonstration of Roll Impulse Dryer	Lavery
3:45pm	- Higher Consistency Processing Applications of X-ray Imaging	Farrington
4:45pm	- Fundamentals of Wet Pressing	Staff
5:00pm	- Refining of Chemical Pulps	Staff
5:30pm --	COCKTAILS	
6:00pm --	DINNER - CEC Dining Room	
7:15pm --	LONG RANGE PLANNING	Committee and IPC Staff

Friday, March 27, 1987

7:15am -- BREAKFAST -- CEC Dining Room

COMMITTEE ACTIVITIES

8:00am	- Discussion of Projects and Planning	Committee & IPC Staff
9:30am	-- BREAK	
9:45am	- Continued Discussion	
10:30am	- Report Preparation	Committee
11:30am	- Adjourn	
	-- LUNCH - CEC Dining Room	

NOTE: The fall Engineering PAC meeting is scheduled for October 22-23, 1987.

ENGINEERING

Project Advisory Committee

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3/26-27/87

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S T A T U S R E P O R T S

To The

Engineering Project Advisory Committee

March 26-27, 1987
The Institute of Paper Chemistry
Continuing Education Center
Appleton, Wisconsin

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

Status Report

to the

ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3309

FUNDAMENTALS OF CORROSION CONTROL IN PAPER MILLS

March 26, 1987

PROJECT SUMMARY FORM

DATE: February 13, 1987

PROJECT NO.: 3309 - Fundamentals of Corrosion Control in Paper Mills

PROJECT LEADER: Ronald A. Yeske

IPC GOAL:

Increase the useful life of equipment by proper selection of materials of construction and by identifying suitable process conditions.

OBJECTIVE:

Improve the useful life of paper machine suction rolls by conducting corrosion and corrosion fatigue studies to establish the mechanisms of failure as the basis for approaches for prolonging roll life.

CURRENT FISCAL BUDGET: $150,000

SUMMARY OF RESULTS SINCE THE LAST REPORT: (October 1986 - February 1987)

Approach

Current laboratory tests do not accurately predict the performance of suction roll alloys in service. This situation is an impediment to timely development of new and improved suction roll alloys, since a heavy reliance is now placed on time-consuming tests of candidate materials as prototype rolls. Furthermore, field tests of protoype materials do not offer guidance regarding desirable metallurgical characteristics of improved roll materials. A better, more predictive test is needed to identify promising suction roll characteristics and incorporate them in new suction roll microstructures.

Consequently, the current effort in this project has been devoted to identifying one or more laboratory tests that correlate with performance of suction roll alloys in the field. Five suction roll alloys are being exposed to several different corrosion and corrosion-assisted cracking tests to identify which laboratory tests correlate with service performance of the five roll alloys. Those tests which discriminate between good and poor alloys will be used to evaluate new alloys considered for suction roll applications, and for the identification of promising new alloys.

Previous Work

A detailed report summarizing the current status of suction roll cracking in the paper industry has been issued to member companies. The corrosion resistance of several suction roll alloys has been examined, but no correlations with service performance were evident. Crack growth rate measurements have been made in the low-growth, near-threshold regime, during exposure to a variety of simulated paper machine white waters. These tests have shown a good correlation with service performance statistics of suction rolls, particularly under high mean stress conditions. Tests have also been conducted to examine the fatigue lifetime of suction roll alloys subjected to cyclic stresses while exposed to simulated white waters. To date, there has been no correlation between service performance and corrosion fatigue lifetime tests conducted in the laboratory. Slow strain rate tests have also been used to evaluate resistance to stress corrosion cracking of suction roll alloys in simulated white waters. Only one of the alloys has shown susceptibility to stress corrrosion cracking, but this alloy has had a good service performance record.

Progress

Near-threshold fatigue crack growth testing has been extended to more aggressive environments to simulate the environmental conditions likely to develop in pits and under fiber deposits. The test environment being examined contains 1000 ppm chloride with the pH lowered to the 1.0 to 1.5 range. These highly acidic conditions represent the acidification that occurs during localized corrosion of high-chromium alloys like the duplex stainless steel alloys tested in the current program.

Crack growth rate data for several suction roll alloys tested in this highly aggressive environment are shown in Fig. 1. As was seen previously in less aggressive environments, the 3RE60 alloy experiences a lower threshold for crack growth and higher growth rates at any applied stress intensity range. This alloy is therefore inferior to the other suction roll alloys examined thus far, including Alloy 63 and Alloy VK-A171. For all three alloys, there has been a significant reduction in the threshold stress intensity for crack growth as a consequnce of acidification of the simulated white water. For all three alloys tested, crack growth would be expected to start from defects found in typical suction rolls (eg., casting defects exposed by hole driling) under typical loading conditions.

Test data are yet to be obtained which will show whether suction roll alloys with good sevice performance are significantly more resistant to crack growth than those tested thus far. Further testing awaits delivery of replacement grip pins which are being plasma-sprayed with a non-conductive oxide insulator.

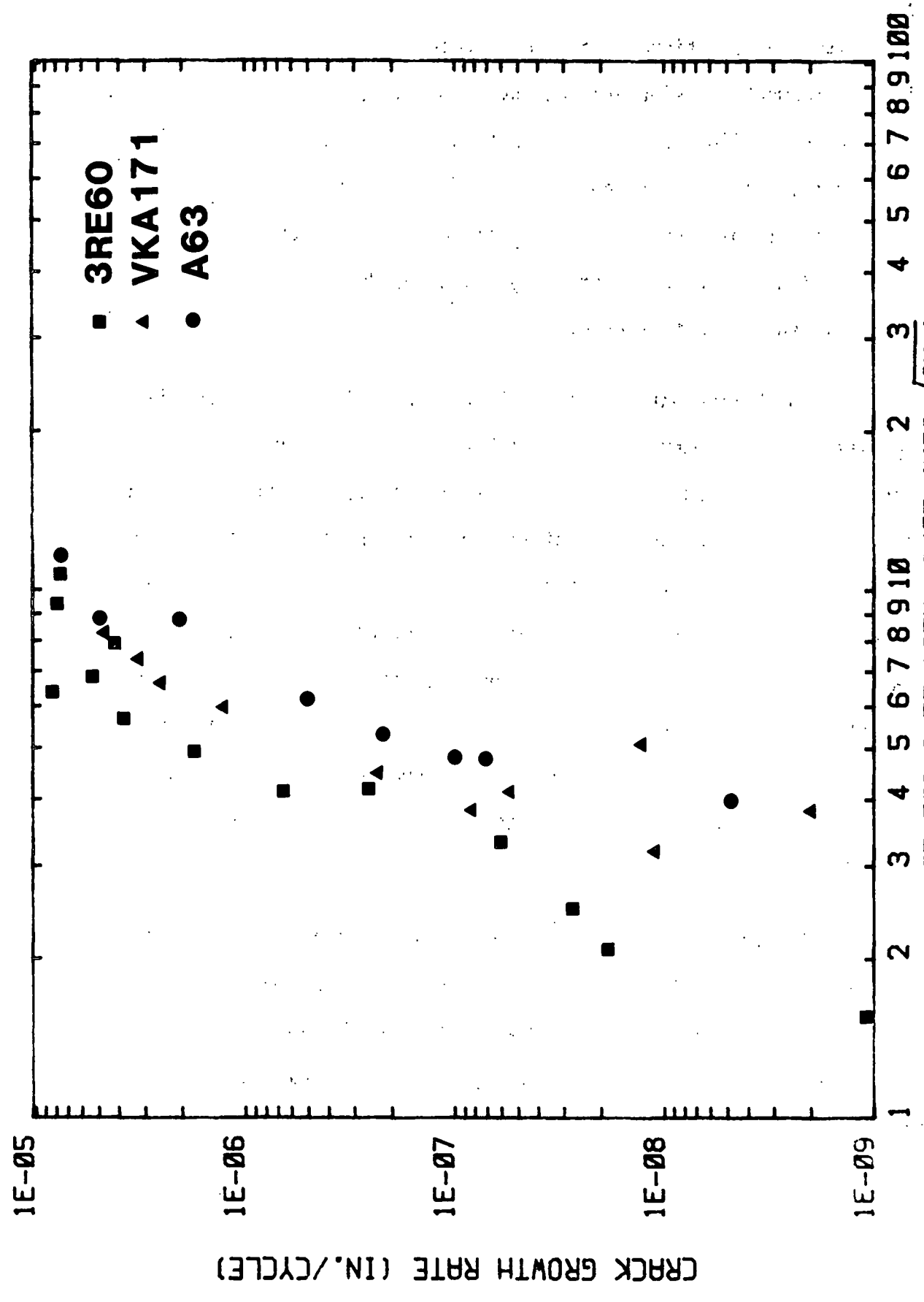


Figure 1. Near-threshold fatigue crack growth data for suction roll alloys tested in a simulated white water containing chloride and thiosulfate and a pH of 1.0 - 1.5.

Corrosion fatigue lifetime tests to determine resistance to crack initiation processes have not yet shown a correlation with the service performance record of the two alloys being tested at present. Alloys 75 and 63 differ widely in their resistance to cracking in service, yet tests in several simulated whitewaters have failed to show a similar difference in cracking resistance. Previous tests in several white waters with pH levels above 3.0 had failed to discriminate between these two alloys. Figure 2 compares recent data obtained with A75 and A63 tested in Environment D containing Cl^-, $SO_4^=$ and $S_2O_3^=$ at a pH of 3.5. Figure 3 compares recent data for stress (S) and number of cycles applied before failure (N) for these two alloys tested in the low pH (1.0 - 1.5) simulated white water, used in the crack growth tests described above. There is no significant difference in the lifetime of these alloys tested under rotating bending, zero mean stress conditions.

A similar failure to discriminate between Alloys 75 and 63 has been obtained with alternating bending tests using notched specimens exposed to this low pH environment.

Further tests have been conducted to determine the magnitude of the residual stresses which accompany autogenous (i.e., without weld filler metal) welding on suction rolls. Cosmetic welding may be done on suction rolls to repair small defects which are uncovered or introduced during machining operations. If these welds are not stress relieved, there may be an opportunity for stress corrosion cracking of the metal in and adjacent to the weld because of the high tensile residual stresses introduced.

Apparatus has been obtained and preliminary tests conducted to determine the residual stress pattern surrounding a ring weld placed on block specimens. These tests involve a hole-drilling technique which uses a strain gauge

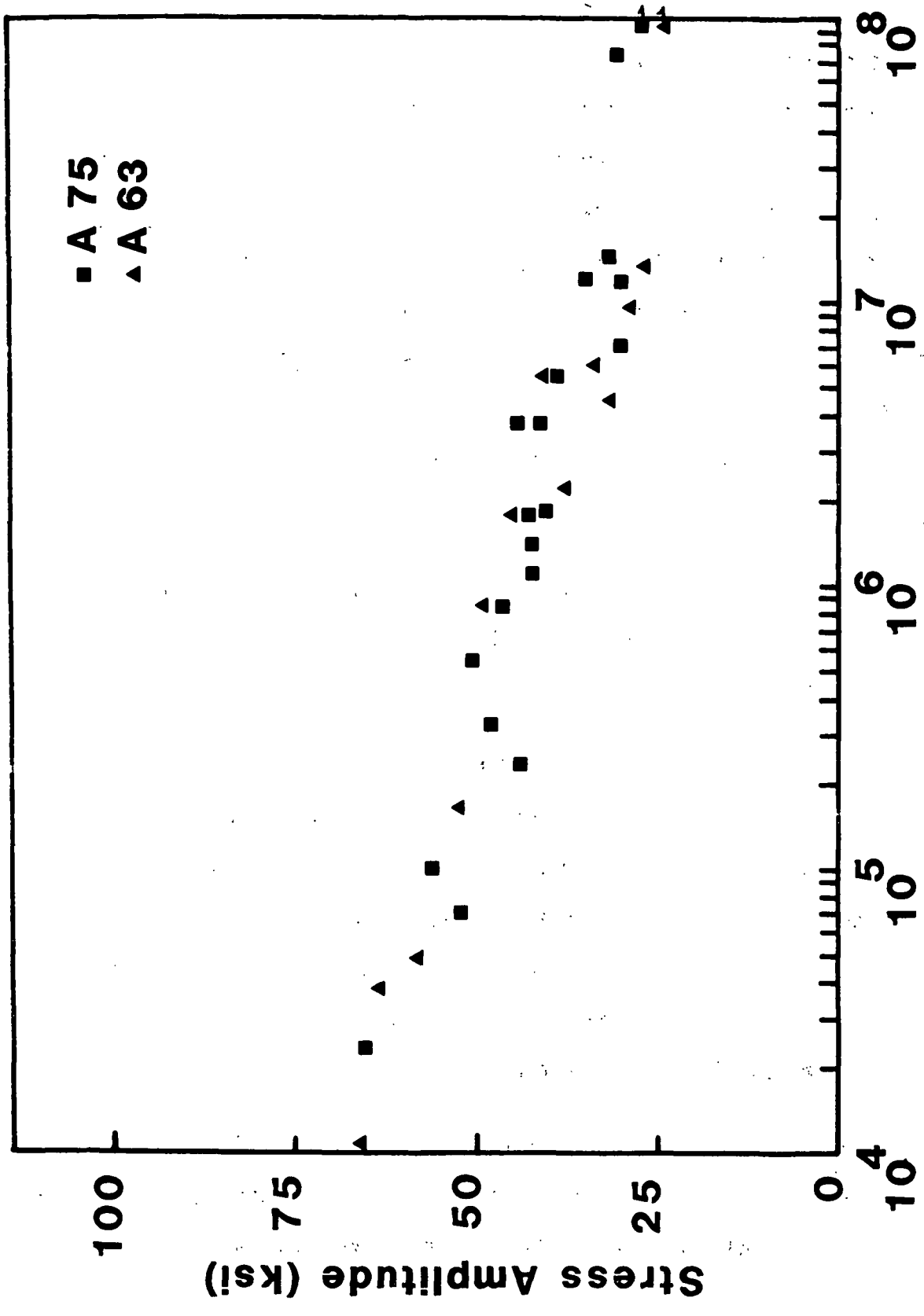


Figure 2. S-N data for Alloys 75 and 63 obtained on smooth specimens subjected to rotating bending in a simulated white water containing chloride and thiosulfate and a pH of 1.0 - 1.5.

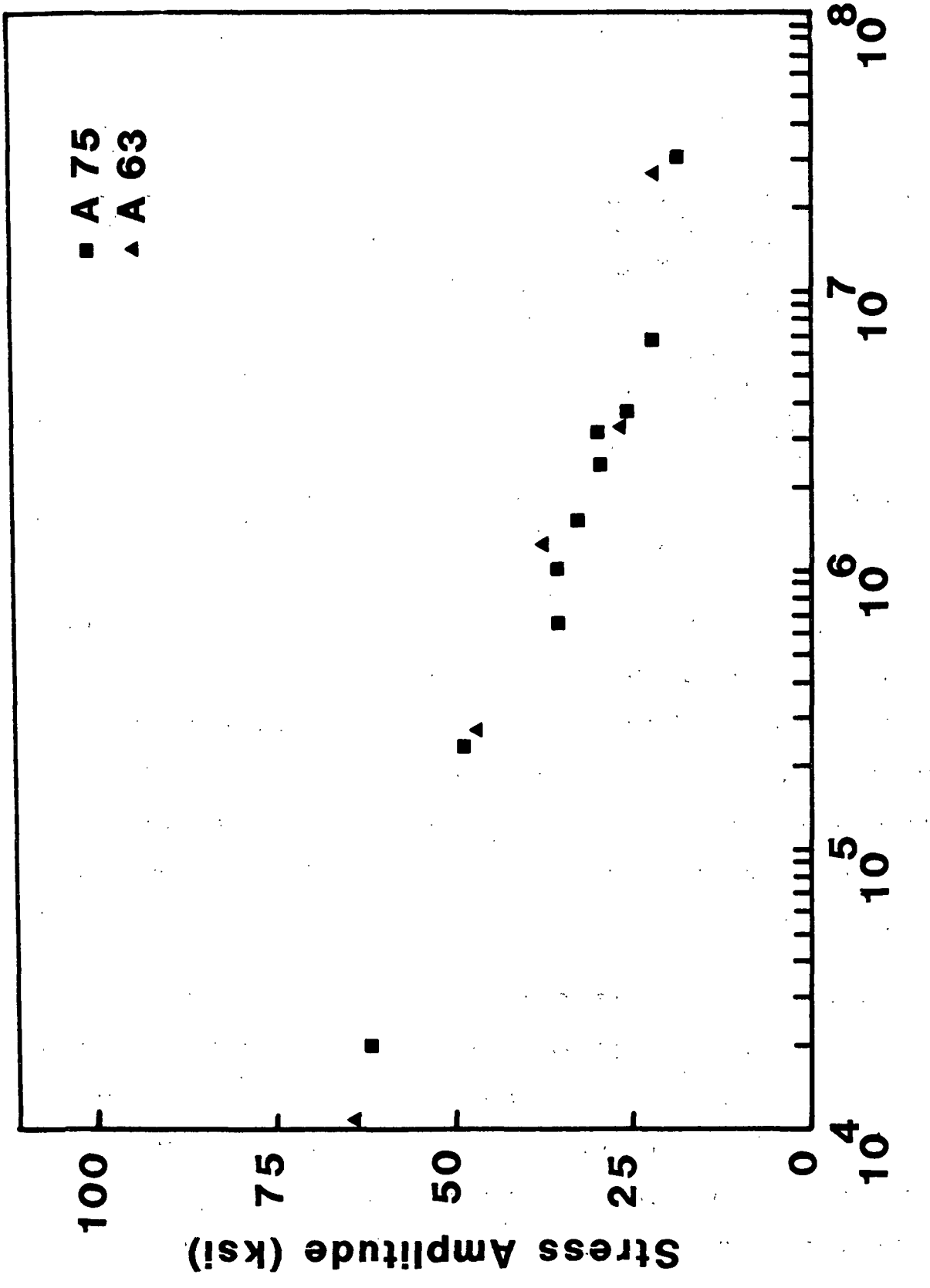


Figure 3. S-N data obtained for Alloys 75 and 63 using notched specimens subjected to alternating bending in a sumulated white water containing chloride and thiosulfate and a pH of 1.0 -1.5.

response to determine the magnitude and direction of the residual stresses in a metal as material is removed by hole-drilling. The specimen with its strain gauge affixed prior to drilling is shown in Fig. 4.

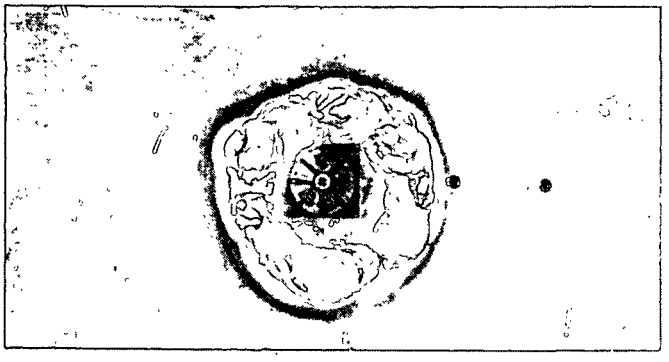


Figure 4. Photograph showing the autogenous weld site and strain gauge rosette prior to hole drilling to determine residual stresses.

The magnitude of the residual stresses surrounding ring welds in two suction roll alloys are shown in Fig. 5. Far from the weld, the surface residual stresses are significant but compressive and are, therefore, unable to promote cracking. Inside the ring weld, however, biaxial tensile stresses approaching the tensile strength of the alloy are found. Stresses on the order of 100,000 psi have been measured, although the reproducibilty of these high stresses is not good.

Ring welds have been made on all of the suction roll alloys in the test program and the residual stress patterns are now being determined. Once determined, these ring weld coupons will be exposed to simulated white water environments to determine if stress corrosion cracking will result. If stress corrosion cracking is found, paper companies may wish to specifiy stress relief heat treatments for cosmetic welds, or may wish to limit the sites where cosmetic welding is allowable.

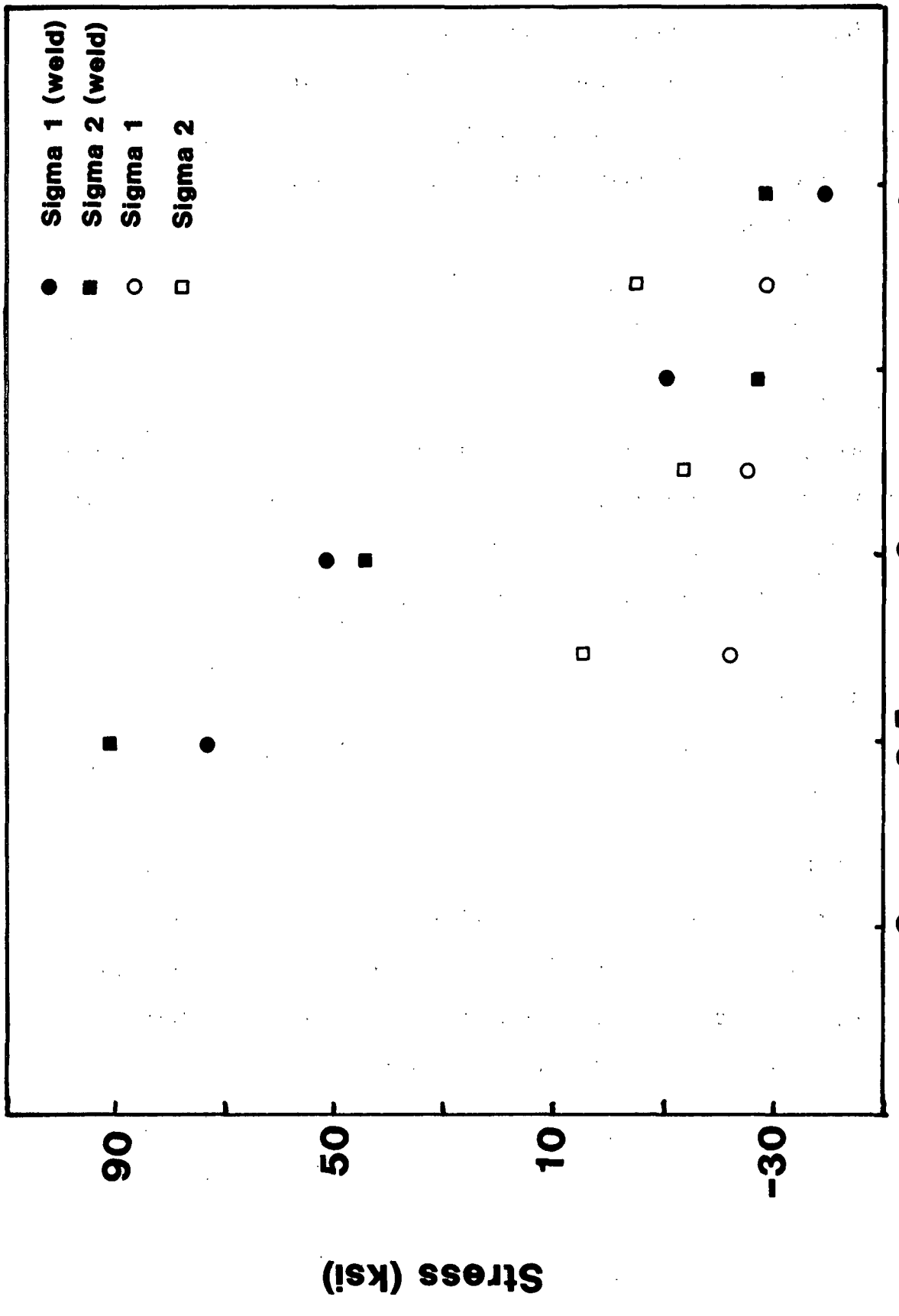


Figure 5. Residual stress pattern surrounding a ring weld placed in a VK-A171 test block.

Additional test materials have been obtained for use in this test program. Additional amounts of VK-A171 have been obtained from a failed suction roll end and from material donated by Valmet-Kubota. Additional material has also been obtained from a special casting of VK-A378. Finally, in response to requests by the PAC to test alternative materials in widespread use, we have obtained and characterized a martensitic stainless steel material (CA15) and a bronze (1N Bronze). These materials are being machined into tests specimens for crack initiation and crack growth testing for direct comparison with the duplex stainless steels tested previously.

PLANS FOR NEXT PERIOD:

In the next reporting period, metallurgical microscopy will be used to characterize the relationship between resistance to crack initiation and growth, and the metallurgical structure and composition of the suction roll alloys. Crack growth rate tests will be conducted on CA15 and 1N Bronze to compare the near-threshold crack growth rate characteristics of these alloys with the duplex stainless steels. Residual stresses will be measured near welds for all of the alloys in the current program and stress corrosion cracking exposure tests will be completed on ring weld coupons.

SIGNIFICANCE TO THE INDUSTRY:

Progress continues to be made in efforts to identify the metallurgical characteristics of suction roll alloys which are resistant to cracking under demanding service conditions. Near threshold fatigue crack growth studies appear to correlate well with the service performance of suction roll materials.

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

Status Report

to the

ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3556

FUNDAMENTALS OF KRAFT LIQUOR CORROSIVITY

March 26, 1987

PROJECT SUMMARY FORM

DATE: February 3, 1987

PROJECT NO.: 3556 - Fundamentals of Kraft Liquor Corrosivity

PROJECT LEADER: D. C. Crowe

IPC GOAL:

Increase the useful life of equipment by proper selection of materials of construction and by identifying suitable process conditions.

OBJECTIVE:

To understand the causes of corrosion and corrosion-assisted cracking of carbon steels exposed to kraft liquor, as a basis for developing methods for reducing corrosion damage in kraft process streams.

CURRENT FISCAL BUDGET: $130,000

SUMMARY OF RESULTS SINCE LAST REPORT: (September 1986 - February 1987)

Modifications in construction and programming of the microprocessor based corrosion monitoring system have extended the capabilities of the present system to make it independent of other (failing) instruments. Laboratory testing is underway to qualify the system for field use. New designs for reference electrodes for use in white liquor storage tanks and clarifiers have been completed and built. Laboratory tests of corrosion rates in simulated green liquors have been completed. Slow strain rate tests have been completed in actual digester liquors from three continuous digesters; these results indicated large differences between mills.

INTRODUCTION:

Improved methods for monitoring corrosion in kraft liquors and tests of corrosion rates both in the mill and under controlled laboratory conditions will yield improved understanding of corrosion processes. That improved understanding will help to identify opportunities for reducing corrosion costs. This project is devoted to the study of general corrosion and stress corrosion cracking in kraft processes.

PROGRESS:

Corrosion Monitoring System

The microprocessor-based corrosion monitoring system described previously was built to collect and store data from an instrument which measured corrosion rate so that data could be easily and reliably gathered. It was designed with the idea that, with the addition of further cards, it could also make the corrosion measurements and replace the corrosion measurement instrument. This modification has been made recently. When the change is complete, the system will be independent of other instruments. Some problems have been encountered with the modification and development of the measurement system. It has been difficult to duplicate the old instrument because, without schematic diagrams, it is unclear just how it does function. Originally, the new system was configured to apply a small potential increment for the linear polarization measurement by slowly increasing the current until the desired polarization was obtained. This was how we thought the old instrument operated. Unfortunately, this method gave values which were dependent on the speed at which the current was increased. The corrosion potential also shifted during the measurement, so that the applied current decreased to nothing. To avoid these problems, the hardware in the system will be changed slightly and a potential increment will

be applied instead. This is a potentiostatic mode of operation used in most modern instruments. It will allow us to correct for the shifting corrosion potential.

Reference Electrode Design

A new design of reference electrode has been constructed for use in white liquor tanks. It is a silver - silver sulfide electrode, as before, but located in a compartment with simulated white liquor solution of known composition. The electrode and solution are in electrical contact with the tank white liquor via a liquid bridge filled with asbestos string. This electrode will not be affected by changes in liquor composition and hopefully will last for longer periods of time. An improved reference electrode will improve the reliability of corrosion monitoring and anodic protection systems.

Green Liquor Study

A laboratory study of corrosion in simulated green liquor has been completed. The results of weight loss tests are summarized in Table 1.

Table 1. Corrosion weight loss measurements in simulated green liquor.

Na_2CO_3 g/L	Na_2S g/L	NaOH g/L	2 weeks	4 weeks	6 weeks	8 weeks
80	20	0	2.0	1.4	0.6	0.3
80	20	20	4.2	4.8	3.8	4.0
80	30	0	2.1	1.8	0.9	0.7
80	30	20	2.7	2.4	1.7	2.0
80	40	20	10.6	5.6	3.5	3.0
120	20	0	2.0	0.8	0.9	1.4
120	20	20	3.4	2.4	2.0	2.0
120	30	0	3.9	2.1	1.7	1.5
120	30	20	4.9	3.3	2.7	2.8
120	40	0	1.5	1.7	1.7	1.9
120	40	20	2.8	1.9	2.8	1.9
160	20	0	1.6	1.5	1.1	1.1
160	20	20	12.3	6.4	5.0	3.9
160	30	0	4.8	2.9	2.8	2.4
160	30	20	2.7	1.3	1.6	2.1
160	40	0	9.2	5.3	3.5	3.5
160	40	20	1.5	2.0	2.4	2.6

Corrosion potential was monitored throughout the weight loss tests. Plots of the corrosion potential versus time have been completed. Polarization behavior in the green liquor solutions at 90°C has also been plotted and will be presented in a report this coming fall.

Slow Strain Rate Testing in Digester Liquors

Slow strain rate tests in actual digester liquors has been continuing, but has been temporarily set aside to complete other tasks. Testing in liquor from one more mill will commence as soon as we are able to obtain a sample.

PLANS FOR THE NEXT PERIOD:

1. Complete improvements to the microprocessor-based corrosion monitoring system and demonstrate use in a mill to monitor corrosion rates in recausticizing liquors.
2. Complete investigations of the effects of liquor constituents on corrosion rates in white liquor by examining combined sulfite-thiosulfate effects.
3. Complete slow strain rate tests to identify whether stress corrosion cracking susceptibility depends on differences in actual continuous digester liquors. The effects of some organic additions are being investigated through the MS research work of J. Hayford.
4. Complete investigations of the effect of liquor velocity on corrosion rates using the rotating electrode apparatus. This is the subject of the MS research of R. Kalishek.

SIGNIFICANCE TO THE INDUSTRY:

Modern corrosion measurement techniques and equipment have been developed and demonstrated for use in kraft liquor systems. Some operating parameters which increase corrosion rate have been identified. The effects of major liquor constituents on corrosivity of white liquor have been determined.

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

Status Report

to the

ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3607

EVALUATION OF STRUCTURAL COATINGS FOR PULP AND PAPER MILL SERVICE

March 26, 1987

PROJECT SUMMARY FORM

DATE: February 1, 1987

PROJECT NO.: 3607 - Evaluation of Structural Coatings for Pulp and Paper Mill Service

PROJECT LEADER: D. C. Crowe

IPC GOAL:

Increase the useful life of equipment by proper selection of materials of construction and by identifying suitable process conditions.

OBJECTIVE:

To rank commercially available paint systems based on their ability to protect structural steel in the aggressive environments found in the pulp and paper mill, especially if applied under less than optimum conditions.

CURRENT FISCAL BUDGET: $25,000

SUMMARY OF RESULTS SINCE LAST REPORT: (September 1986 - February 1987)

Tests coupons have been obtained and racks have been constructed. Some racks have been installed in mills and arrangements have been made to install more in the near future.

INTRODUCTION:

Failure of structural coatings is a costly problem for pulp and paper mills. Effective recoating is especially difficult. Often, it is impractical to clean the surface completely or to apply the coating under optimum conditions. In these situations, it is important to select a coating which is less

sensitive to application conditions. This project will focus on identifying such a coating.

PROGRESS:

Racks to hold test panels have been designed and constructed. They each hold 24 KTA-Tator panels which are 4 inch by 6 inch. The racks are 2 feet high and 4 feet wide and are constructed of marine grade plywood coated with epoxy paint. They are labeled clearly with the Institute's name, a contact person and a telephone number to call in case of problem. A rack, installed in a mill location is illustrated in Fig. 1.

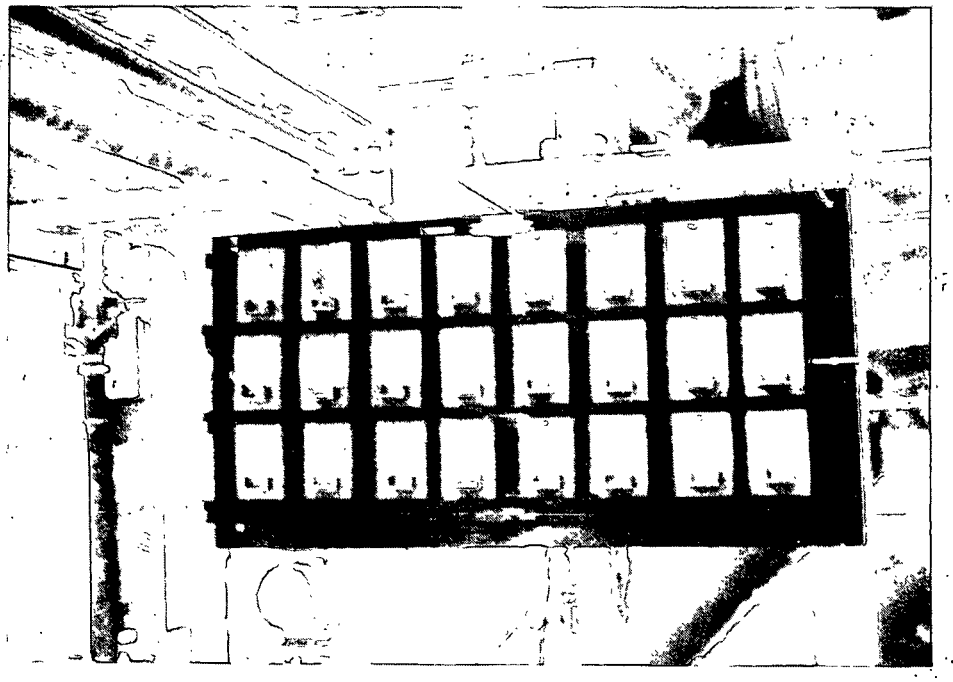


Figure 1. Paint panel test rack installed in a mill location.

The racks have been installed in a mill in the upper area of the recovery boiler superstructure, near the bleach washer, near the wet end of the paper machine and in the chemical preparation area. Racks will be installed in similar locations at other mills.

PLANS FOR THE NEXT PERIOD:

1. Begin exposures of uncoated panels in selected locations at cooperating mills, including the recovery boiler superstructure, paper machine wet end, bleach plant and other troublesome areas.
2. Identify coatings systems to be tested.
3. Prerusted coupons will be cleaned and coated with candidate paint systems, then returned to the mill until they fail or the test program is terminated.

SIGNIFICANCE TO THE INDUSTRY:

This project will provide mills with an independent assessment of the long-term reliability of structural coatings for pulp and paper mill applications.

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

Status Report

to the

ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3606

CORROSION IN HIGH YIELD PULPING PROCESSES

March 26, 1987

PROJECT SUMMARY FORM

DATE: February 3, 1987

PROJECT NO.: 3606 - Corrosion in High Yield Pulping Processes

PROJECT LEADER: D. C. Crowe

IPC GOAL:

Increase the useful life of equipment by proper selection of materials of construction and by identifying suitable process conditions.

OBJECTIVE:

Use electrochemical methods to understand corrosion and corrosion-assisted cracking processes occurring in high yield pulping to identify potential problems and solutions.

CURRENT FISCAL BUDGET: $40,000

SUMMARY OF RESULTS SINCE LAST REPORT: (September 1986 - February 1987)

Basic studies of corrosion rate as determined by weight loss and polarization behavior have been completed in alkaline sulfite, bisulfite and acid sulfite solutions at 90°C. Liquor analyses have been performed to confirm chemical composition. No significant corrosion problems were encountered. Expertise in testing in these environments has been gained and groundwork has been laid for investigations of the effects of additives. A Hastelloy C276 test cell has been constructed and work at 150°C has commenced.

INTRODUCTION:

Despite the proliferation of high yield pulping processes and equipment, there is a lack of published information on the corrosion effects of chemical additives to TMP and CTMP processes. One of the main reasons for this lack of information is that mechanical pulping is a relatively new technology and most companies prefer to keep their CTMP chemistries proprietary. Problems with chloride cracking of steaming vessels, sulfuric acid condensation and organic acid formation have been encountered.

PROGRESS:

Chemical Analysis

Sulfite solutions used in the study were analyzed to determine their actual composition. The analyses are summarized in Table 1.

Table 1. Chemical composition of test solutions.

Nominal Composition	Actual Composition
8 g/L Na_2SO_3 pH 7	5.98 g/L Na_2SO_3 0.59 g/L Na_2SO_4
12 g/L Na_2SO_3 pH 7	8.34 g/L Na_2SO_3 1.11 g/L Na_2SO_4
14.3 g/L Na_2SO_3 pH 10	16.57 g/L Na_2SO_3 1.04 g/L Na_2SO_4
57.4 g/L Na_2SO_3 pH 10	58.7 g/L Na_2SO_3 2.66 g/L Na_2SO_4
30 g/L $NaHSO_3$ pH 4	26.4 g/L Na_2SO_3 0.89 g/L Na_2SO_4
12 g/L $NaHSO_3$ pH 4	10.02 g/L Na_2SO_3 0.44 g/L Na_2SO_4
30 g/L $NaHSO_3$ pH 1.5	52.4 g/L Na_2SO_3 1.1 g/L Na_2SO_4

The analysis for Na_2SO_3 and $NaHSO_3$ was reported in terms of Na_2SO_3. At pH 1.5, substantial additions of SO_2 were made to acidify the solution. This accounts for the much higher concentration of Na_2SO_3 in that solution. Small amounts added at pH 4 seemed to have no effect on final composition.

Polarization Study at 90°C

Polarization curves were generated for 304 and 316 stainless steels in the test environments to identify differences through a range of pH and are illustrated in Figs. 1-4. Conditions under which the 304 behavior was significantly different from the 316 could be used to determine where the more expensive 316 is really required.

Weight Loss and Potential Monitoring at 90°C

Results of weight loss tests are summarized in Table 2. In the cases where pH decreased significantly, the corrosion rate was higher, especially in the vapor phase. The higher corrosion rates did not seem to be caused by lower pH, otherwise corrosion rates would have been higher in the more acidic solutions. The decrease in pH during the test may have been due to hydrolysis of corrosion products, or to some unknown factor.

Although no significant corrosion rates have been identified, these tests form a basis for investigation of the effects of additives. Expertise in mixing solutions and conducting tests in these environments has been gained.

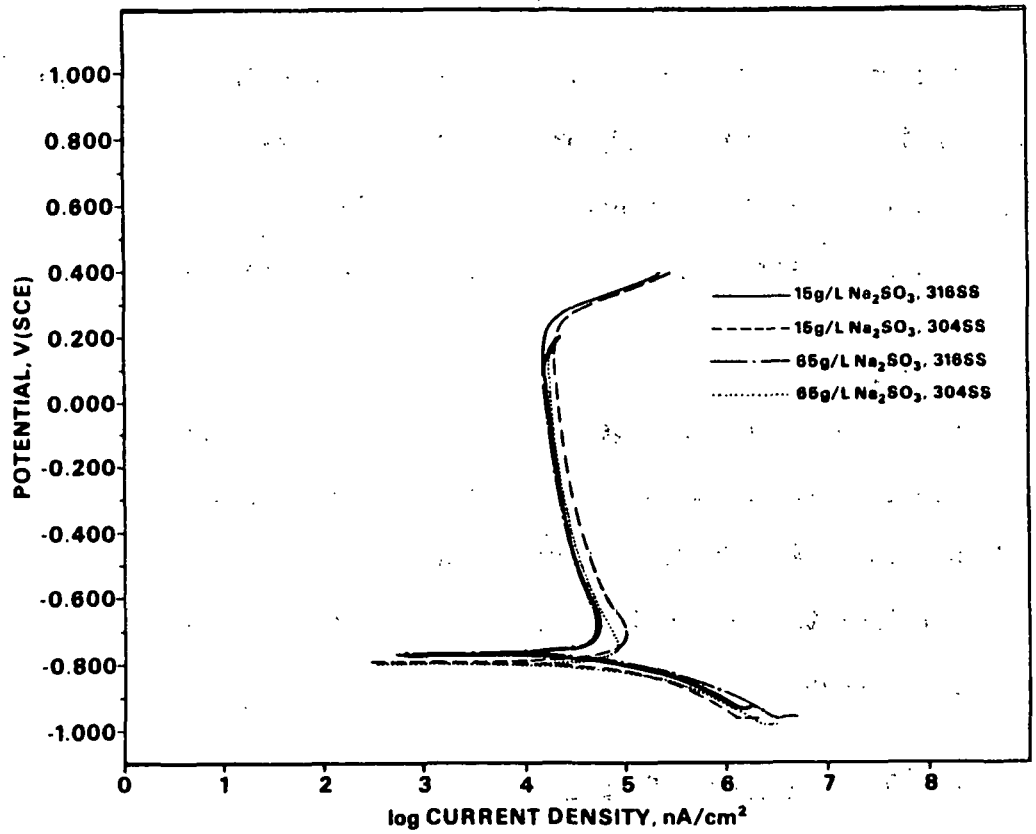


Figure 1. Polarization behavior of 304 and 316 stainless steels, 15 and 65 g/L Na_2SO_3, pH 10, 90°C.

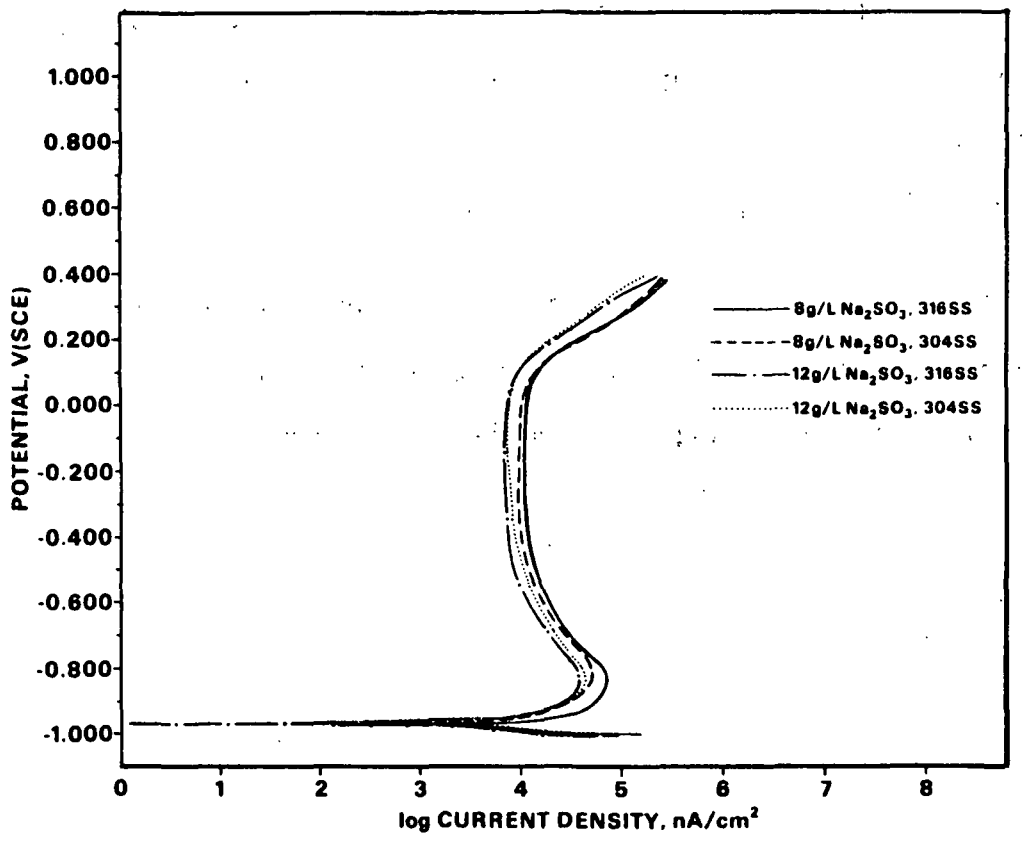


Figure 2. Polarization behavior of 304 and 316 stainless steels, 8 and 12 g/L Na_2SO_3, pH 7, 90°C.

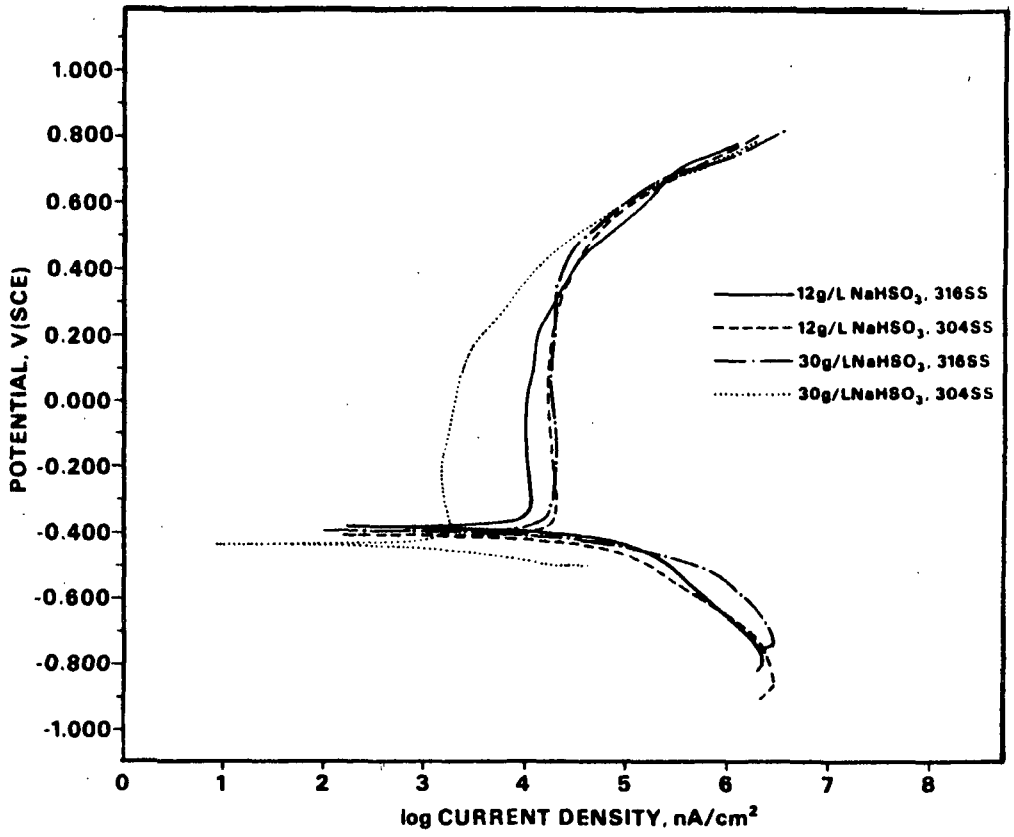


Figure 3. Polarization behavior of 304 and 316 stainless steels, 12 and 30 g/L $NaHSO_3$, pH 4, 90°C.

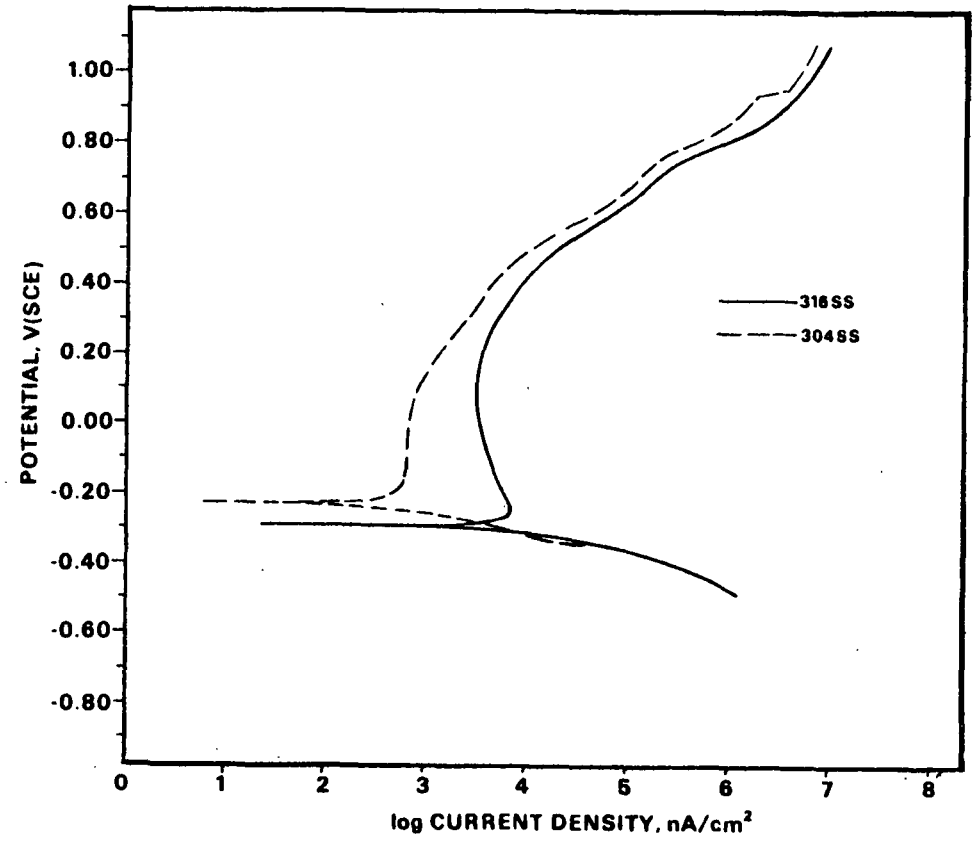


Figure 4. Polarization behavior of 304 and 316 stainless steels, 30 g/L $NaHSO_3$, pH 1.5, 90°C.

Table 2. Corrosion rates determined by weight loss tests.

Environment	Phase	Material	Corrosion Rate, mpy	Initial pH	Final pH
8 g/L	liq.	304	<0.1	10.12	7.82
Na_2SO_3	liq.	316	<0.1		
pH 10	vap.	304	<0.1		
	vap.	316	<0.1		
12 g/L	liq.	304	0.12	10.16	3.84
Na_2SO_3	liq.	316	0.11		
pH 10	vap.	304	0.12		
	vap.	316	0.11		
14.3 g/L	liq.	304	<0.1	7.44	2.58
Na_2SO_3	liq.	316	<0.1		
pH 7	vap.	304	0.13		
	vap.	316	0.12		
57.4 g/L	liq.	304	0	7.23	6.7
Na_2SO_3	liq.	316	0		
pH 7	vap.	304	<0.1		
	vap.	316	<0.1		
30 g/L	liq.	304	<0.1	4.18	N.A.
$NaHSO_3$	liq.	316	0		
pH 4	vap.	304	0		
SO_2 addn.	vap.	316	0		
12 g/L	liq.	304	0	4.22	N.A.
$NaHSO_3$	liq.	316	0		
pH 4	vap.	304	0		
SO_2 addn.	vap.	316	0		
30 g/L	liq.	304	0.1		
$NaHSO_3$	liq.	316	0		
pH 1.5	vap.	304	0		
SO_2 addn.	vap.	316	0		

Results of potential monitoring during weight loss tests are illustrated in Figs. 5-11. At pH 10 (Fig. 5 and 6), the corrosion potential of both 304 and 316 increased steadily throughout the test indicating that the materials were becoming more passive. In the 12 g/L Na_2SO_3 solution, the pH fell significantly during the test. There was no significant difference between the steels. At pH 7, the steels showed the same behavior in the solution con-

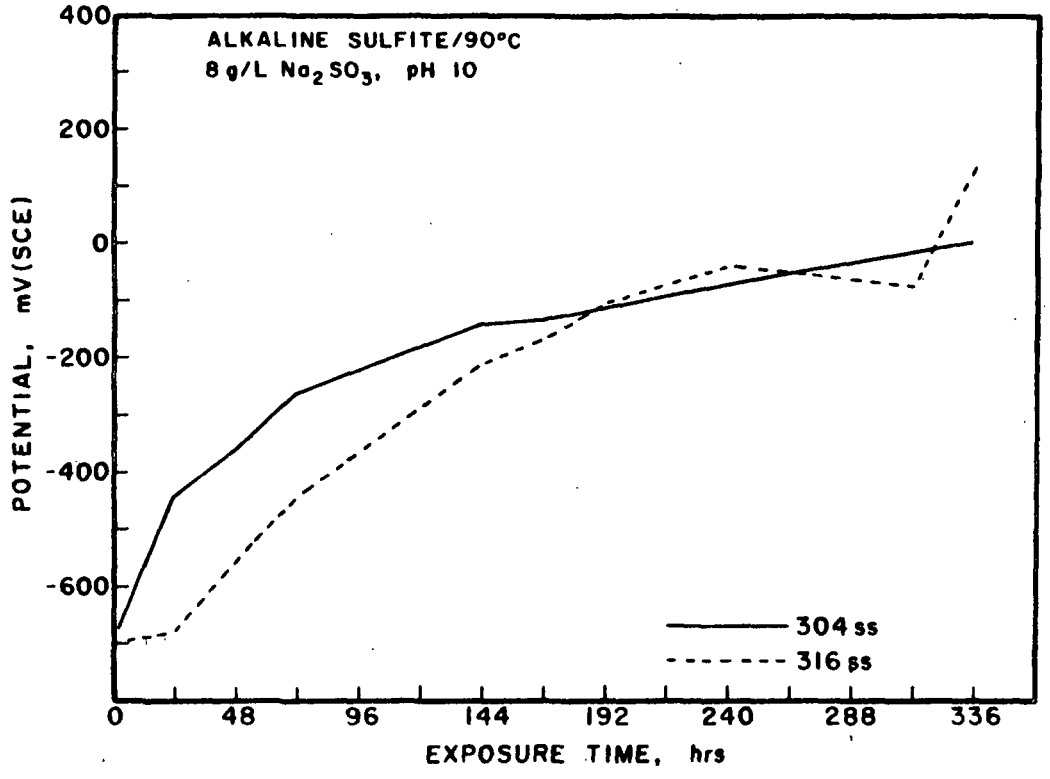


Figure 5. Corrosion potential versus time of 304 and 316 stainless steels in alkaline sulfite solution containing 8 g/L Na_2SO_3 (pH 10) at 90°C.

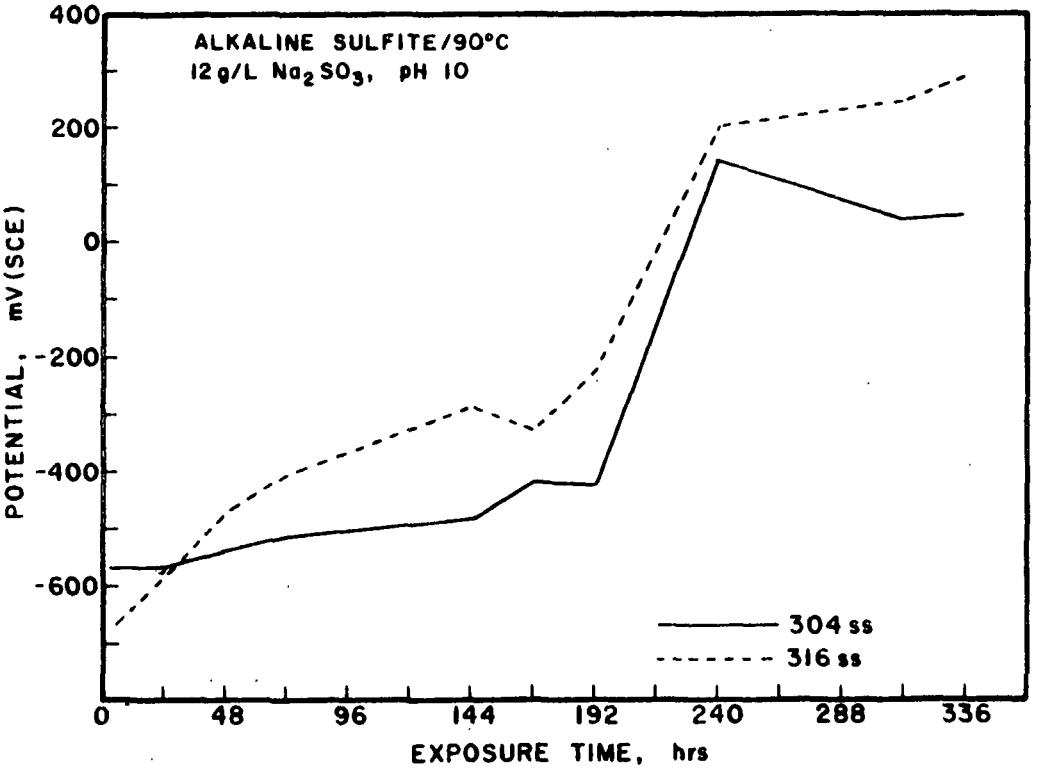


Figure 6. Corrosion potential versus time of 304 and 316 stainless steels in alkaline sulfite solution containing 12 g/L Na_2SO_3 (pH 10) at 90°C.

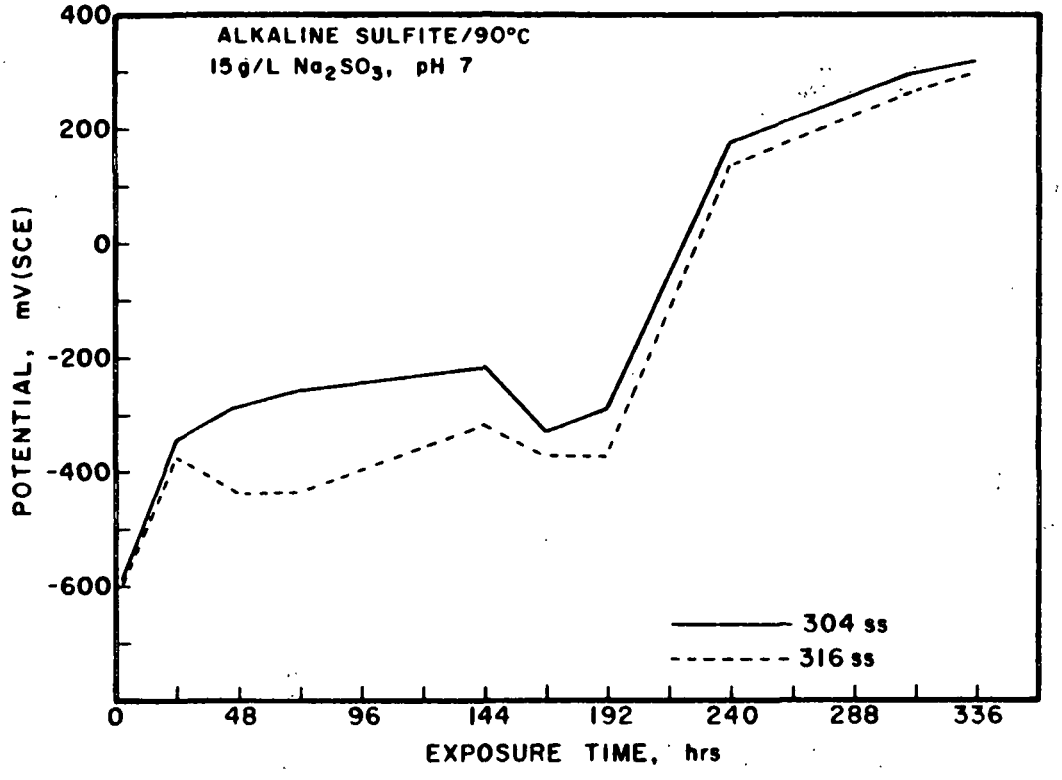


Figure 7. Corrosion potential versus time of 304 and 316 stainless steels in alkaline sulfite solution containing 14.3 g/L Na_2SO_3 (pH 7) at 90°C.

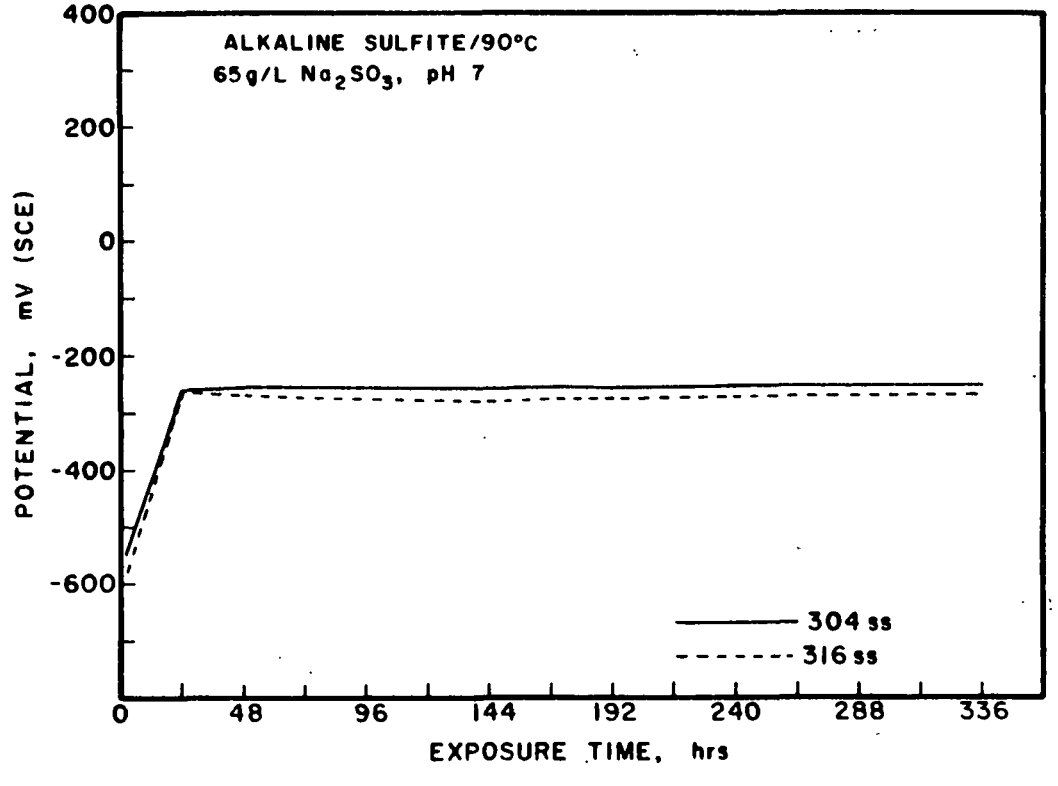


Figure 8. Corrosion potential versus time of 304 and 316 stainless steels in alkaline sulfite solution containing 57.4 g/L Na_2SO_3 (pH 7) at 90°C.

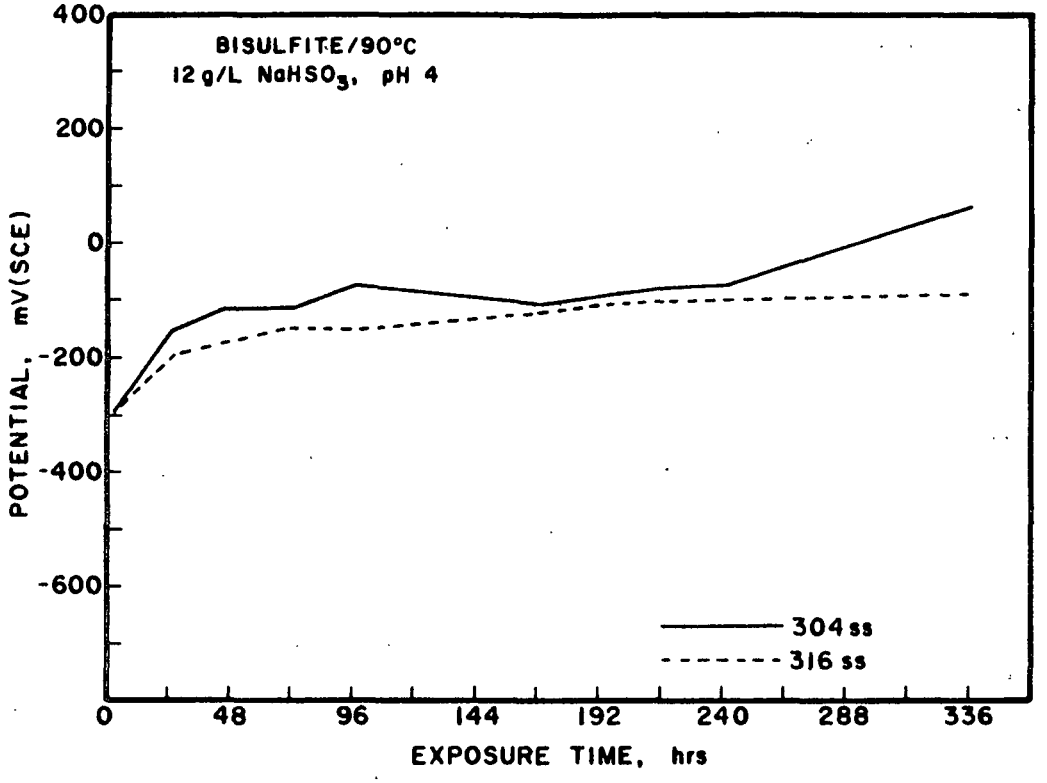


Figure 9. Corrosion potential versus time of 304 and 316 stainless steels in bisulfite solution containing 12 g/L $NaHSO_3$ (pH 4) at 90°C.

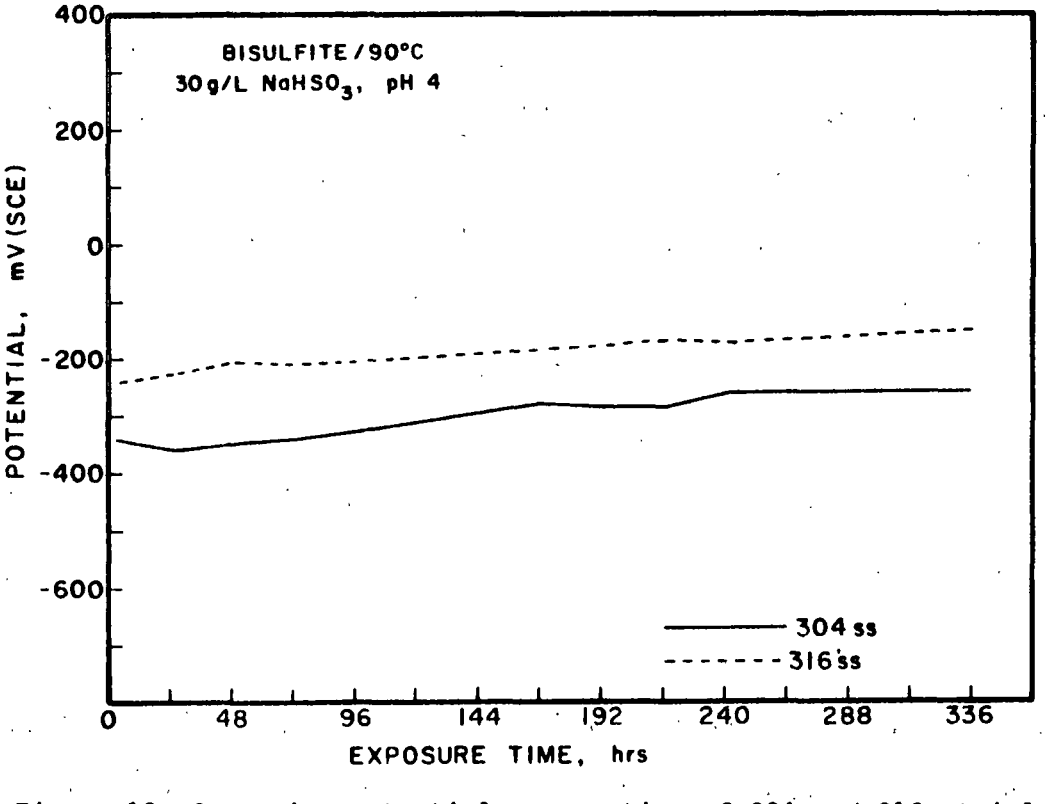


Figure 10. Corrosion potential versus time of 304 and 316 stainless steels in bisulfite solution containing 30 g/L $NaHSO_3$ (adjusted to pH 4 with SO_2) at 90°C.

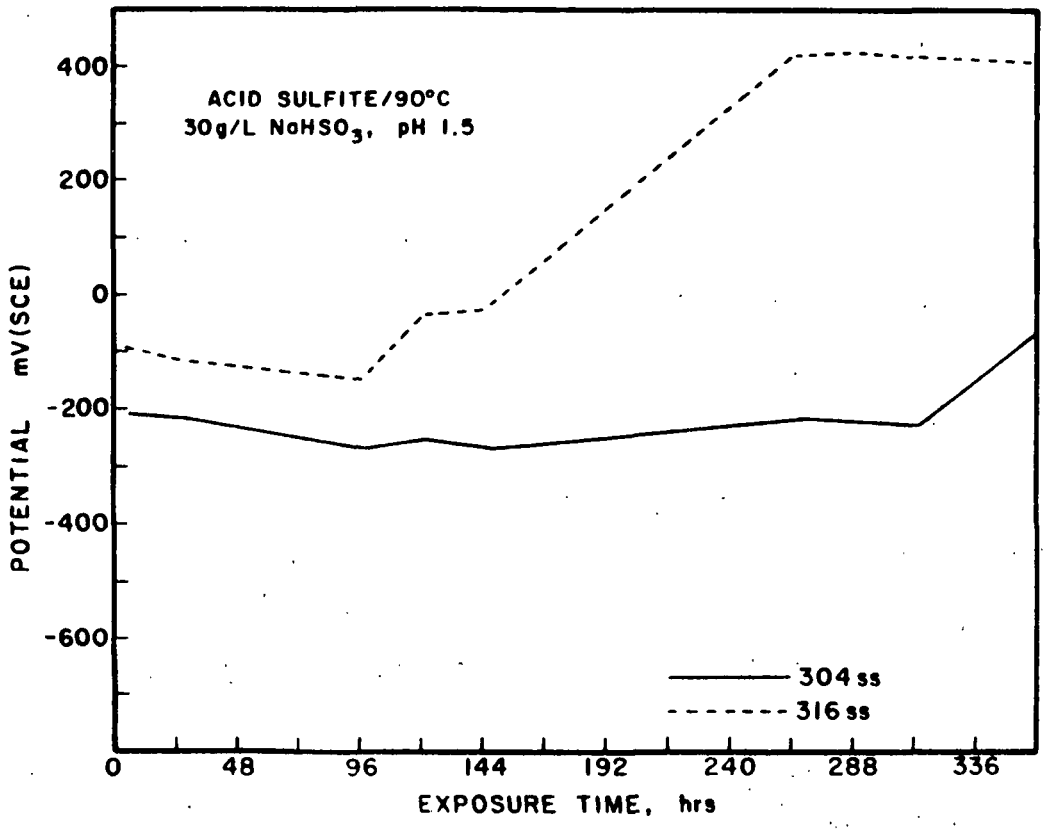


Figure 11. Corrosion potential versus time of 304 and 316 stainless steels in acid sulfite solution containing 30 g/L $NaHSO_3$ (adjusted to pH 1.5 with SO_2) at 90°C.

taining 14.3 g/L Na_2SO_3 (Fig. 7). The increasing potential may have been due to the decreasing pH. In the solution containing 57.4 g/L Na_2SO_3 (Fig. 8), the corrosion potential reached a steady value after 24 hours and remained there. The more concentrated solution apparently prevents the steel from moving further into the passive range or the pH from changing. Corrosion potential was also stable in the more acidic bisulfite solutions (pH 4) as illustrated in Fig. 9. In the acid sulfite solution, the 316 stainless steel attained a much more noble potential than the 304 steel (Fig. 10).

Equipment Construction

A Hastelloy test cell was constructed for use at 150°C. Difficulties with welding delayed completion. Grips for slow strain rate testing were also made. An external reference electrode compartment has been added to the cell for reliable potential control.

PLANS FOR THE NEXT PERIOD:

1. Obtain samples of TMP and CTMP filtrate from mills for analysis to determine typical conditions.
2. Complete weight loss and potential monitoring at 150°C in alkaline sulfite, bisulfite and acid sulfite liquors for types 304 and 316 stainless steel in the liquid and vapor phases.
3. Perform slow strain rate tests at 150°C for 316 stainless steel to determine susceptibility to stress corrosion cracking in the liquid and vapor phases.
4. Study the effects of various chemical additives on general corrosion and stress corrosion in the most troublesome cases including $Na_2S_2O_4$, Na_2CO_3, $Al_2(SO_4)_3$, H_2O_2, NaCl and perhaps $Na_2S_2O_3$, Na_2S and organic acids.
5. For the most aggressive environments, rank alternative materials which may be employed to solve a specific problem.

SIGNIFICANCE TO THE INDUSTRY:

These studies will provide a basis for decisions regarding materials selection for TMP and CTMP equipment.

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

Status Report

to the

ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3470

FUNDAMENTALS OF DRYING

March 26, 1987

PROJECT SUMMARY FORM

DATE: February 10, 1987

PROJECT NO.: 3470 - Fundamentals of Drying

PROJECT LEADER: Hugh Lavery

IPC GOAL:

Reduction of the "necessary minimum" complexity in number and/or sophistication of process steps.

OBJECTIVE:

To develop an understanding and a database sufficient for the commercialization of advanced water removal systems, based on high-intensity drying principles. This new technology will reduce capital costs, increase machine productivity, reduce the amount of energy used, and improve paper properties.

CURRENT FISCAL BUDGET:

$150,000 from Institute funds, plus $350,000 through a Department of Energy grant (as Project 3595). This grant is for a total amount of $1.5 million over four years; 1987 is the second grant year for the project.

The Fourdrinier Kraft Board Group has funded part of the work on linerboard conversion issues in impulse drying with a grant of $30,000.

SUMMARY OF RESULTS SINCE LAST REPORT: (October 1986 - February 1987)

Project 3470 has continued to emphasize research on impulse drying, with the objective of gathering data to support development of the process to the point of commercialization. Impulse drying may be defined as drying a wet sheet under short time, high pressure and high temperature conditions. Previous work demonstrated that impulse drying produces very high drying rates

at low drying energy requirements, offering the potential for smaller dryer sections and improved energy use. Furthermore, impulse drying enhances a wide variety of paper properties, with the potential for improved products, better property control, and the substitution of lower cost furnishes at equal product strength.

The principal project activity for the period has been the construction of a pilot roll impulse dryer. This apparatus has been designed to produce samples of impulse dried paper and board of sufficient size to test the conversion performance of impulse dried products and to provide a demonstration of the process in a realistic roll geometry. The first phase of the construction of this equipment will be completed by mid-February, 1987. By late March, the equipment should be de-bugged and available for testing.

The status of the equipment as it was in late January may be seen in Fig. 1. The impulse dryer rolls are each two feet in diameter and two feet in face width. The upper roll is heated by electrical infrared heaters . Roll surface temperatures are controlled using the signals from surface junction thermocouples mounted in the upper roll. The nip width of this machine is approximately one inch when the press felt is installed. Nip residence time will be adjusted by changing the machine speed. The initial design speed is 300 feet per minute, which may be increased if required for subsequent work. The conditions in the nip accurately simulate what a web would see in a high-speed machine despite the low design speeds. A second nip to facilitate two-sided impulse drying experiments will be built in late 1987, if needed.

Experimental work has also continued, using the bench-scale electro-hydraulic platen press impulse dryer. The principal experiments involved

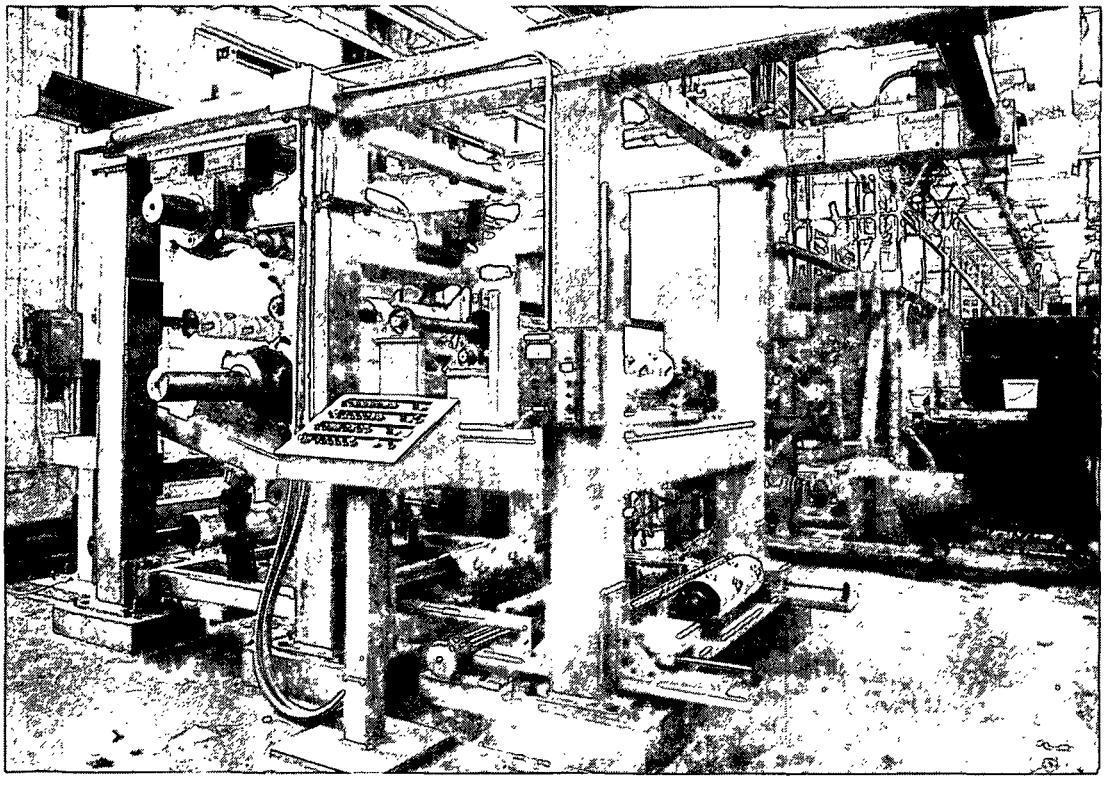


Figure 1. Operators-side photo of roll impulse dryer.

studying the effects of impulse drying very wet sheets. Earlier work had indicated that, for sheets below 50% solids, the final dryness of impulse dried webs was nearly independent of the initial sheet moisture content. This effect has now been confirmed for virgin kraft linerboard sheets as wet as 15% solids, as shown in Figure 2. Impulse drying from any point in what is now the wet press moisture range will achieve similar final sheet dryness. There may thus be a significant potential for capital savings by using impulse dryers in place of wet presses.

The specific energy requirement in BTU's per pound of water removed also decreases as wetter sheets are impulse dried. Recent work (Figure 3) has confirmed this observation, and shows that a minimum in the specific energy

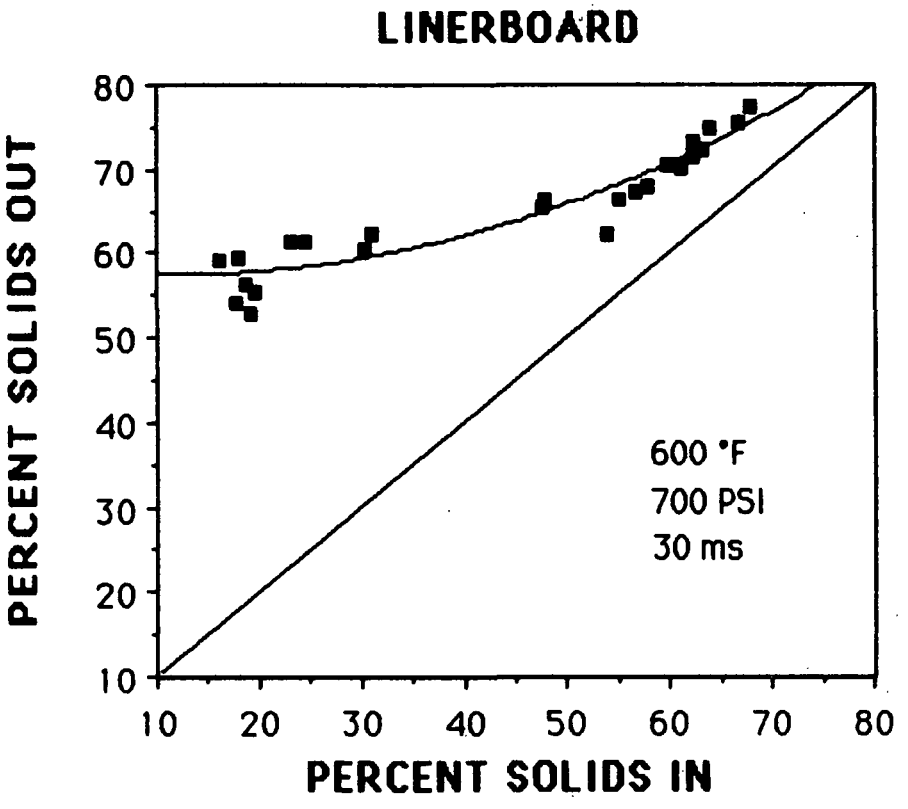


Figure 2. The percent solids achieved during impulse drying depends only weakly on the ingoing percent solids.

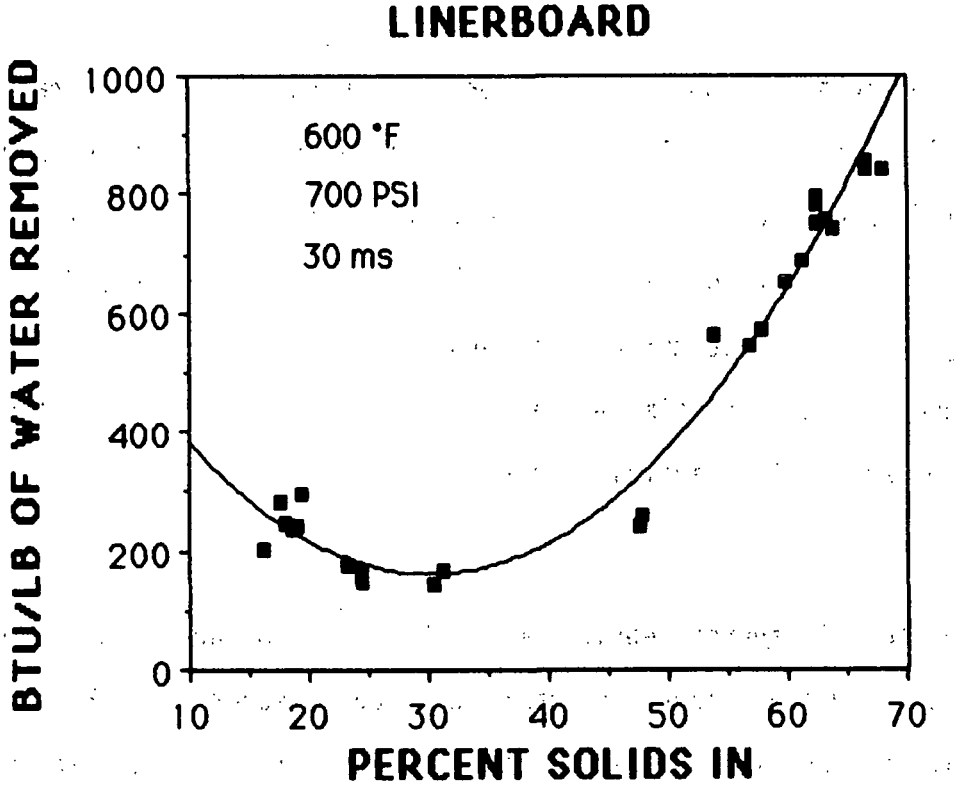


Figure 3. Specific energy use in BTU per pound of water removed during impulse drying.

requirement of 200 BTU/lb of water removed occurs at about 25% solids for linerboard. Below 25% solids, the specific energy requirement gradually increases, due to the energy requirements to heat the large amounts of water in the sheet to the boiling point. The combination of decreasing specific energy requirements and increasing water removal rates as wetter sheets are dried leads to a very weak dependency of total energy requirements for impulse drying on initial sheet moisture content over the 25% to 50% solids range. Thus, impulse drying in place of at least part of the conventional wet pressing operation may have economic value.

Additional data and calculations on these expanded energy use studies should be available by meeting time.

Student research related to project 3470 includes Harry Dundore's MS project on the mechanisms of strength development in CMP under impulse drying conditions, which is scheduled for completion by mid-March. Further MS work has just begun, including projects by W. Stenz, W. Bartz, and D. Arnold. A new PhD project by G. Rudemiller to study heat transfer phenomena under impulse drying conditions is scheduled to begin in March.

PLANS FOR THE NEXT PERIOD:

Following the start-up period on the pilot roll impulse dryer, which is expected to last through the end of March, a series of experiments will be run whose primary objective is to test the conversion performance of impulse dried sheets. Large web samples will be made on the IPC web former, impulse dried, and converted. Linerboard and medium will be tested for corrugating and combined board conversion performance, including printing quality. A light-weight coating rawstock will be impulse dried, coated, and tested for print quality.

Similar appropriate tests will be performed on newsprint and writing paper. These experiments will answer the major question about the suitability of impulse dried sheets for use in the production of several important grades, while providing data on water removal and density development to confirm earlier bench-scale results.

SIGNIFICANCE TO THE INDUSTRY:

Impulse drying is a new technology which offers the potential for reduced capital costs, increased machine productivity, reduced energy use, and improved paper properties. Commercialization of impulse drying could produce fundamental changes in the pulp and papermaking process as a whole, as equivalent products can be made from less costly furnishes with lower capital and energy costs.

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

Status Report

to the

ENGINEERING PROJECT ADVISORY COMMITTEE

Project 3479

HIGHER CONSISTENCY PROCESSING

March 26, 1987

PROJECT SUMMARY FORM

DATE: February 10, 1987

PROJECT NO.: 3479 - Higher Consistency Processing

PROJECT LEADER: Ted Farrington

IPC GOAL:

Reduction in complexity of forming systems

OBJECTIVE:

To develop experimental and computational techniques necessary to better understand the behavior of fiber suspensions over a range of consistencies encompassing both current and potential future operations.

To apply a better knowledge of fiber suspension microrheology to increase paper machine wet-end consistencies from current levels of 0.1-1.5% to 2.0-10.0%, depending on grade, without loss of machine speed or paper physical properties.

Ultimately, to apply any new knowledge or techniques developed in this area to other high speed multiphase flow problems of interest to the industry.

CURRENT FISCAL BUDGET: $150,000

SUMMARY OF RESULTS SINCE LAST REPORT: (October, 1986 - February, 1987)

Background

High consistency forming has the potential of reducing both capital and energy costs, and improving formation and physical properties control. Previous attempts have produced paper which appeared felted, with inferior in-plane properties. This can be traced to lack of control of out-of-plane fiber orien-

tation in the sheet. At high consistencies, this orientation is largely fixed within the headbox and slice. Without the ability to measure fiber orientation at actual process conditions, process development must proceed by trial and error. The initial objective of this project has been to develop some means for measuring the fiber orientation distribution in concentrated fiber suspensions during high speed flows.

Flash x-ray radiography (FXR) will be used to study fiber orientation distribution in both idealized and more practical flow situations. The objective of any idealized flow experiments will be to assess to what extent fiber orientation distribution can be controlled under the best of conditions. If significant results cannot be realized here, it would be unlikely that any improvement can be made in practical flows.

Although the primary application of this new imaging technique is in the fiber suspension area, it has demonstrated potential for providing new knowledge in other areas of importance to the industry. Two of these areas are black liquor spraying and high solids coating flows. Each of these is being pursued as student (MS or PhD) research at this time. Proposals have been submitted to DOE to augment current funds in the fiber suspension and black liquor spray areas. These proposals request $400,000 and $1,500,000, respectively. In addition, the black liquor spray and coatings research have direct member-company support on the order of $20,000 each.

Progress

The need for state-of-the-art image analysis capability in this work was made clear at the last review. Several other activities at IPC also suffer for lack of such instrumentation. Therefore, a significant amount of time was devoted to preparing a proposal to DOE for a $170,000 RCI image analyzer. The

proposed black liquor spray research was the primary justification. This proposal was submitted on December 1 and a decision is due in May of 1987. Image analysis requirements will be met by contracting time on other instruments until this proposal or the black liquor proposal (decision due 9/87) are decided upon.

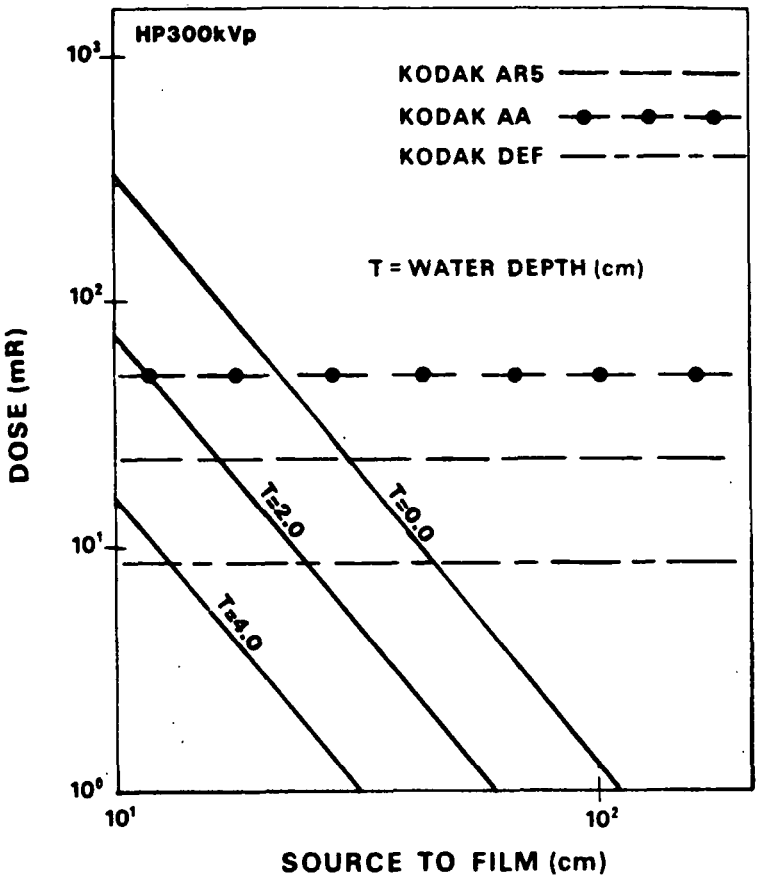
A grant was received from a member company to construct a black liquor spray facility and obtain the FXR system required for this work. Construction has begun and the FXR device (H-P 150KVp) is now being tested in the lead room. The spray facility is being constructed in the South Research (Recovery) Building.

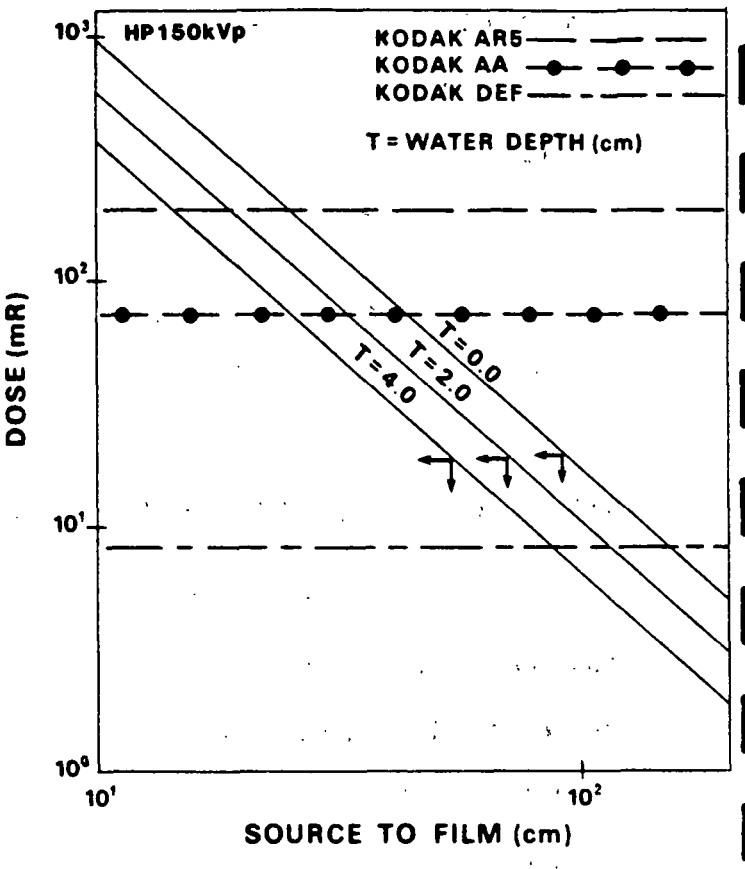
The performance of all three FXR systems (HP-300, HP-150 and LLL-150) has been characterized. Figure 1 shows the radiation dose versus distance from source and thickness of water in front of film. X-ray intensities required to expose three popular flash x-ray films to density 1 are also indicated. Effective spot sizes for each instrument have been determined by edge sharpness and hole camera techniques. Finally, resolution and contrast versus water depth have been determined for metal tracer fibers. In the fiber suspension work, it is clear that resolution becomes a factor before contrast or penetration when using heavy metal tracer fibers. This is contrary to the black liquor spray case where contrast becomes critical before resolution or exposure.

Several alternative tracer fibers were evaluated during this period with mercury-loaded and silver-coated being the main candidates. Within the range of pulp species tested to date (mainly southern pine kraft), the following conclusions have been reached.

1. Neither system offers contrast comparable to metal filaments.

2. Mercury is probably impractical as it is easily removed from the fibers.





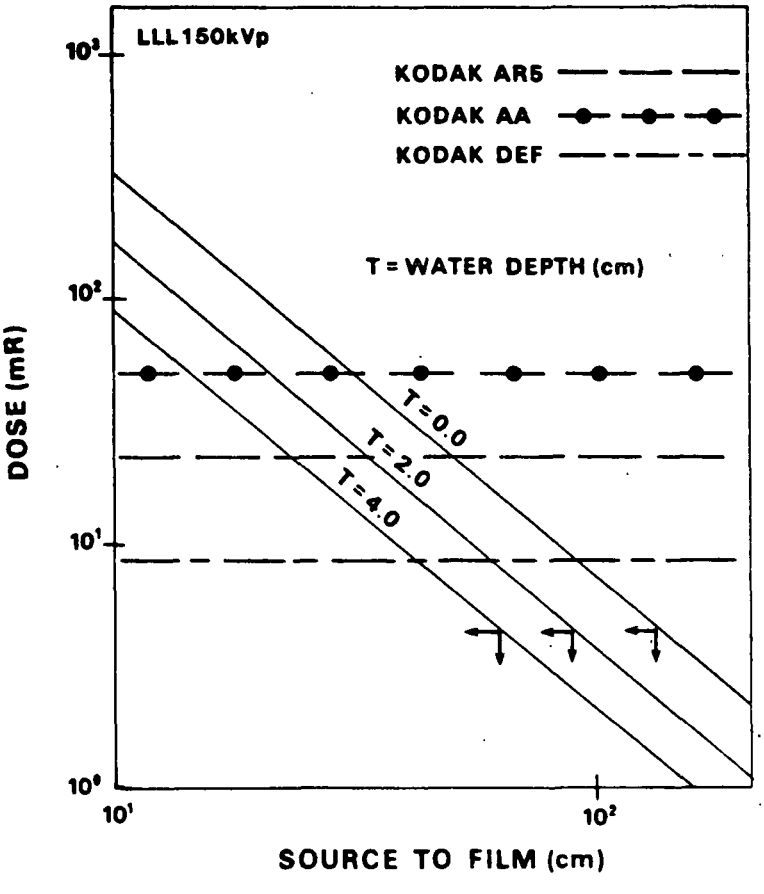


Figure 1. FXR performance.

3. Several microns of silver deposit are required to give any reasonable contrast and this significantly changes the fiber character.

4. A problem with any natural fiber approach will be image analysis. The inhomogeneity of fiber length and linearity will make quantitative fiber orientation data difficult to achieve.

Current Activities

Based on these results, we have decided to proceed with a model fiber system. Nylon fibers of 50 micron diameter and 1, 2, 3 mm lengths have been obtained for the bulk fibers in our first test. Tracer fibers will comprise 25 metal filaments coated with nylon. Indications are that silver fibers offer several advantages over tungsten and may therefore replace tungsten as the metal of choice.

The first ideal flow devices will be simple planar and circular converging channels. They are now being assembled. Our objectives in this study are straightfoward.

1. To determine to what extent fiber orientation can be achieved during high speed flow of a concentrated fiber suspension in certain converging flows.

2. To compare the results obtained in this case with the best possible, both experimentally and theoretically.

3. To ascertain the relative importance of fiber-fiber interactions and turbulent fluctuations in determining fiber orientation distribution.

To achieve these objectives, we plan to assess fiber orientation distribution in the four experiments shown in Fig. 2, utilizing converging channels. The test indicated by quadrant 1 is the high speed flow of a concentrated fiber suspension. Best possible orientation should be achieved in quadrant 3 - slow elongational flow. Turbulent fluctuations will dominate in quadrant 2, while fiber-fiber interactions will be important in quadrant 4. By comparing the results of these four experiments, we should gain some insite regarding the relative importance of several fiber-fiber and fiber-liquid interactions. These tests are characterized in more detail in Table 1.

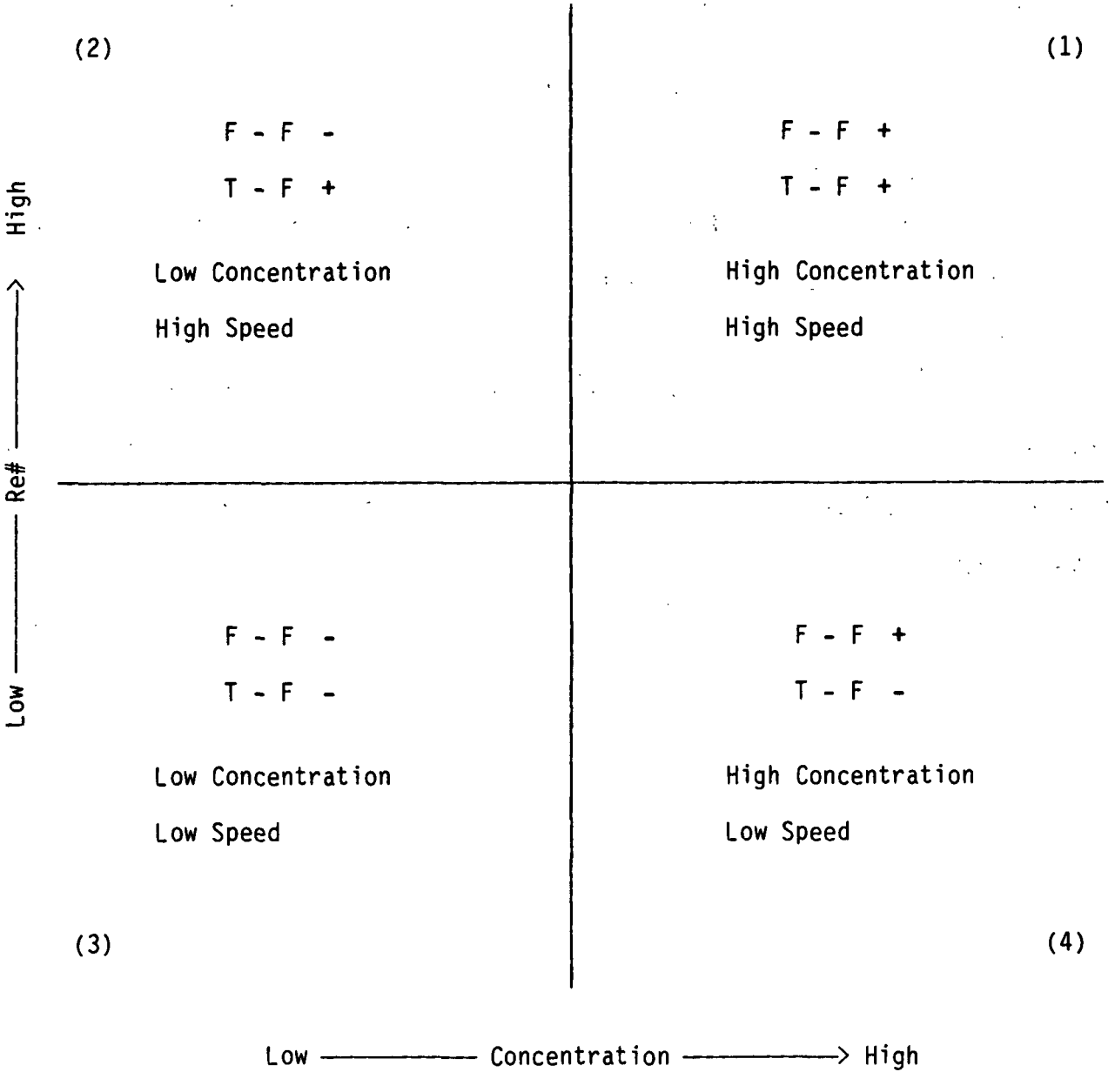
Table 1. Experimental plan.

Quadrant (Fig. 2)	% Consistency	Velocity	Fiber-Fiber Interaction	Re #	Imaging
1	High	High	+	+	FXR
2	Low	High	-	+	Optical
3	Low	Low	-	-	Optical
4	High	Low	+	-	FXR

At the last review, it was suggested that we continue our efforts in the area of soft x-ray imaging for formation measurements. The images were digitized on a scanning microdensitometer at UW-Madison with the intention of processing the data at IPC. After much work, we have concluded that it is utterly futile to process such large (1000x1000) matrices on the current IPC computer. We are proceeding to study the images with an off-site image analysis system.

PLANS FOR THE NEXT PERIOD

1. To have produced all the images required to complete the converging flow studies. Analysis will depend upon image analysis proposal status.



* F - F = fiber-fiber interaction.

T - F = turbulence fluctuations

Figure 2. Fiber orientation distribution tests (converging flows)*.

2. To perform MC forming empirical tests with some headbox.

3. To complete x-ray formation analysis.

SIGNIFICANCE TO THE INDUSTRY:

Higher consistency forming has the potential to reduce both capital and energy costs. Perhaps more important is the potential to obtain novel three dimensional sheet properties.

Flash x-ray radiography has demonstrated the ability to provide very unique information regarding several multiphase flow problems of interest to the industry. Current applications include black liquor sprays, coating flows, and impulse drying.